Government of Canada Gouvernement du Canada

Province of British Columbia

FRASER RIVER ESTUARY MANAGEMENT PROGRAM

STATUS REPORT ON WATER QUALITY IN THE FRASER RIVER ESTUARY - 1987

Standing Committee on the Fraser River Estuary Water Quality Plan

December 1987

Fraser River Estuary Management Program

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British Columbia Cataloguing in Publication Data

Main entry under title:
Status report on water quality in the Fraser River Estuary. -- 1987-

Triennial.
At head of title: Fraser River Estuary Management Program.
ISSN 0836-1886

1. Water quality - British Columbia - Fraser River Estuary. I. Fraser River Estuary Management Program (Canada). Standing Committee on the Fraser River Estuary Water Quality Plan. II. Fraser River Estuary Management Program (Canada)

TD227.B7S72 363.7'3942'097112

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SUMMARY

The Standing Committee assessed the quality of water, sediment, and biota by examining recent environmental data, and reviewing results of existing research and monitoring programs, and comparing these data with Water Quality Objectives issued by the B.C. Ministry of Environment and Parks. These Objectives indicate potential impairment to specified water uses in specific waterbodies when exceeded. They have been adopted by FREMP as a starting point against which to evaluate water quality. Objectives have not been developed for all contaminants of concern in all environmental compartments.

It is the conclusion of the Standing Committee that information currently available is not sufficient to define statistically the status of water quality in the estuary. A more comprehensive and coordinated approach to monitoring combined with special research projects is required to provide the necessary information. However, based on the very limited available data, Water Quality Objectives developed to this point are usually met in the study area. Confirmation is required both in the main channels and especially in sloughs and side channels.

Physical and chemical characteristics in effluents are not easily measured in ambient waters of the Fraser River Estuary due to dilution, tidal action, natural variability, and other factors. Data for water, sediments, and biota indicate that the water quality differs by geographical area. Some areas of specific degradation exist. The worst area is the North Arm, where the flow is relatively low and to which a large number of effluents are discharged. Conditions in the Main Stem are not significantly degraded, and the Main Arm is intermediate between the North Arm and Main Stem. Some toxic contaminants are of concern in the Estuary and require further attention. Examples of these include chlorophenols, polycyclic aromatic hydrocarbons, and dioxins.

There is a zone of severe degradation over a limited area of Sturgeon Bank attributable to the discharge from the Iona Sewage Treatment Plant. The relocation of the outfall from the Treatment Plant should help improve degraded conditions on Sturgeon Banks, which have not changed since 1976.

The water chemistry of the Main Stem, Main Arm, and North Arm was quite similar. During the 1979 to 1980 period, total cadmium was detected more frequently in water in the Main Arm than in the North Arm, while total chromium values were significantly higher near Steveston Island than at the Pattullo Bridge on the Main Stem.

A 1980 survey of Fraser River fish from the Banks to its headwaters at Moose Lake concluded that many metal levels in fish muscle remained the same or declined when compared with results of a 1972 survey. Past elevated metal levels were attributed to man's activities, except for copper which was higher upstream from developed areas. The cause for the high copper upstream is unknown. The number of fish analyzed in a 1985 survey was insufficient, compared to 1972 and 1980, to assess statistically significant trends in the estuary.

Bioconcentration of metals from sediments to benthic organisms was apparent for copper, lead, and zinc in a large number of organisms in the Main Stem, Main Arm, and North Arm. Some differences were noted between data for metals in sediments and benthic organisms from 1985 and those reported earlier. These differences could be real or may be artifacts of sampling location or time of year. In the Main Stem, copper and iron in some benthic organisms appeared to increase, while in the Main Arm, copper and lead in sediments appeared to double between 1980 and 1985. However, an adequate data base is not yet available on which to judge whether conditions are deteriorating.

The sloughs and sidechannels are the most sensitive areas for fish and aquatic life in the estuary. There is some concern with occasional low dissolved oxygen, habitat loss, contamination by organics and metals, and sedimentation and resuspension of contaminants.

Low dissolved oxygen, habitat loss or alteration, and contamination by metals and organic compounds are the major problems on a limited area of Sturgeon Bank. A specific problem on the Banks is the potential for metals being made available at the salt wedge-freshwater interface.

Bacteriological contamination in Boundary Bay has prevented commercial bivalve harvesting for the last two decades. In tributaries to Boundary Bay, dissolved oxygen levels can decrease seasonally to lethal levels.

The water chemistry of Sturgeon and Roberts Banks is similar throughout, although there was a high level of variability between sampling occasions and in comparison to previous studies. Seven organic compounds and eight inorganic compounds were detected in sediments in 1986; however concentrations of all organics, except phthalate esters, were within twice the detection limit and were likely below concentrations of concern. The eight inorganic compounds detected were at similar, relatively uniform levels. Runoff from agricultural lands has been identified as one source of this contamination, and this should be examined further.

The continuation of existing monitoring programs and research activities by universities, government agencies and other interested parties is essential for a thorough understanding of the complexities of the estuary and cause/effect relationships of contaminants. Recommendations are made in the status report for further studies to address areas of the estuary with degraded water quality. A more complete list of recommended special studies will be provided in the Water Quality Plan. Recommendations will also be

made in the Water Quality Plan for a mechanism to establish and revise Water Quality Objectives, and on the necessary research and monitoring programs.

ACKNOWLEDGEMENTS

The Standing Committee expresses its appreciation to all speakers and attendees of the February 1987 workshop. Their input was integral to the Committee's evaluation of the status of the Fraser River Estuary.

The Standing Committee would also like to thank Ms. L.D. Rounds of the B.C. Ministry of Environment and Parks, who typed several drafts of this report. Dr. A. Smith was contracted to prepare a draft of the proceedings of the workshop.

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1. INTRODUCTION

On October 10, 1985, an agreement was signed by the B.C. Ministry of Environment, federal Departments of Environment and Fisheries and Oceans, and the North Fraser and Fraser River Harbour Commissions which initiated the Fraser River Estuary Management Program (FREMP). FREMP is the culmination of work begun under the Canada/British Columbia Fraser River Estuary Study (FRES) in the period 1977 to 1984. In order to improve existing approaches to water quality management of the estuary, the Standing Committee on the Fraser River Estuary Water Quality Plan was established under FREMP in 1986.

The Standing Committee is responsible for developing a Status Report on water quality in the Fraser River Estuary, on a regular basis. The purpose of the Status Report is to assess environmental data and identify current and potential water quality issues and problems in the estuary. This information is to be used to revise ongoing monitoring and research programs, to revise or develop appropriate Water Quality Objectives, and to influence waste management practices within the estuary.

Several mechanisms were used to develop the Status Report. First, a technical workshop with representatives from federal and provincial agencies, universities, and consultants was held in Vancouver in February, 1987. At the workshop, twenty-five scientific and administrative papers were presented on current work in the estuary. Abstracts of these presentations and associated questions and answers are included in the Appendix. In addition, three work groups were convened at the workshop to priorize water quality issues based upon the presentations and the group's knowledge of the estuary. Their findings are summarized in Chapter 3 and are detailed more fully in the Appendix.

The status of the estuary is reviewed in Chapter 2. The conclusions of the Standing Committee on the status of water quality in the Fraser River Estuary are presented in Chapter 4. These conclusions are based on information presented at the workshop, results of other current monitoring and research, and input from Standing Committee members.

2. STATUS OF WATER QUALITY IN THE ESTUARY

The most extensive review to date of Fraser River water quality took place during the Fraser River Estuary Study. A series of technical reports dealing with discrete topics such as water chemistry, bacteriological quality, and industrial discharges was issued in 1979 and the early 1980's. A summary report incorporated the major findings of the technical reports (Water Quality Work Group 1979). Swain and Holms (1985) updated the Fraser River Estuary Study findings in a technical report which also proposed provisional Water Quality Objectives. That review presented the most recent overall status information available.

The portion of the Fraser River under consideration as defined in the 1985 FREMP Agreement is downstream from Kanaka Creek, including Pitt River downstream from the outlet of Pitt Lake, Sturgeon Bank, Roberts Bank, and Boundary and Semiahmoo Bays (Figure 1). The following discussion will be structured according to the five sub-basins: the Main Stem from Kanaka Creek to the bifurcation at New Westminster, including the Pitt River; the North Arm from New Westminster to Sea Island; the Main Arm from New Westminster to Westham Island; Sturgeon and Roberts Banks; and Boundary and Semiahmoo Bays and their tributaries. Tributaries to the Fraser River and Boundary Bay, although discussed in this report, are not (except the Pitt River) within the study area.

Water Quality Objectives are limits set for physical, chemical, or biological characteristics of water, biota, or sediment to protect designated uses. Water Quality Objectives are based upon scientifically-determined values, known as Water Quality Criteria. The application or development of Water Quality Criteria on a site-specific basis, considering designated water uses and local circumstances, leads to the development of Water Quality Objectives. The Objectives are meant as policy guidelines for use by managers in protecting water uses in specific waterbodies. The Objectives can be used as a reference against which the status of water quality in a particular waterbody can be checked.

The scope of the Objectives is limited to characteristics which might be significantly influenced by man's activities at present or in the foreseeable future. In Tables 1 to 6, the words "not applicable" are provided for some waterbodies or reaches of waterbodies. This indicates that a particular characteristic will probably not be affected by man's activities in that reach or waterbody.

Water Quality Objectives discussed in this chapter are those published or in preparation (Tables 1-6) by the B.C. Ministry of Environment and Parks (MoEP). The Water Quality Objectives are MoEP Policy for guiding the protection and use of the specific waterbody. It should be noted that MoEP does not require that Objectives, except for those for fish (currently for PCB's and chlorophenols in tissue), be met within initial dilution zones (up to 100 m) of point source discharges (Ministry of Environment and Parks 1986). Criteria referenced are from the B.C. MoEP, the Canadian Council of Resource and Environment Ministers (CCREM), the U.S. Environmental Protection Agency (EPA), and other sources. All metals data and related Objectives are for total metals, unless otherwise specified.

Provisional Objectives are set where the information available about local conditions (e.g., water quality, water uses, aquatic life, waste discharges) and/or the Water Quality Criteria for a substance are inadequate for the establishment of scientifically-defensible Objectives. Short-term and long-term Objectives may be used where existing water quality does not suit all desired water uses, and it is feasible to improve the water quality over time.

Through FREMP, a mechanism has been adopted to develop and revise Water Quality Objectives for the study area with the cooperation and approval of the five signatory agencies (Standing Committee on the Fraser River Estuary Water Quality Plan in prep.).

There are limitations inherent in any ambient monitoring undertaken in a system as complex as the Fraser River Estuary. For example, it is some-

times not feasible to monitor locations at an optimal frequency. Historically only main channel areas have been monitored, and other areas such as sloughs and sidechannels have received only a minimal monitoring effort. Analytical capabilities improve continually, providing evidence of problems which were not recognized in the past. Characteristics for which there are no Objectives are being measured, although there are not sufficient numbers of these data to determine cause/effect relationships.

In order to present an accurate assessment of the status of Fraser River Estuary water quality, a comparison should be provided where possible with conditions reported in the past. However, much of the data presented in this report were not collected with sufficient replication (e.g., fish data reported in Swain 1986) or frequency to provide statistically significant comparisons to other work. This evaluation is based largely on ambient monitoring, providing information on general background conditions, (not necessarily extremes), of water, sediment, and biota at locations outside of known effluent plumes.

2.1 FRASER RIVER MAIN STEM AND TRIBUTARIES

2.1.1 THE TRIBUTARIES

The four major tributaries to the Fraser River in this reach are Kanaka Creek, the Pitt River, the Coquitlam River, and the Brunette River. Only the Pitt River to Pitt Lake is in the FREMP Study area. On average, the Pitt River increases the flow in the Fraser River by about 1%, the Coquitlam River by 0.1%, and each of Kanaka Creek and the Brunette River by 0.01%. In the January/February low-flow period, the tributary contribution can be up to 3% of the flow. The effect of these tributaries on Fraser River water quality has not been detected.

The following discussion is based on water quality sampling by MOEP conducted between 1972 and 1984, when sampling was discontinued. The water quality of the four tributaries was generally considered to be as good or

better than the Fraser River. The four tributaries had "soft" water which provided a low to moderate buffering capacity. Total metals values, except as noted in the following discussion, were below detection limits and within Provincial working Water Quality Criteria for the protection of aquatic life. In all four tributaries, total copper, iron, and lead exceeded CCREM guidelines. Total nickel exceeded CCREM guidelines (1987) in the Coquitlam River as did total chromium and zinc in the Brunette River. Dissolved oxygen levels were high (near saturation) in the Pitt and Coquitlam Rivers, slightly lower than saturation in the Brunette River, and generally good (although with some values as low as 4.6 mg/L) in Kanaka Creek. Fecal coliform counts in the tributaries were at least as low as those in the Fraser River during the summer.

Draft Water Quality Objectives are being prepared for the aforementioned tributaries (Swain in prep.), and are summarized in Table 6. Most of the draft Objectives are being achieved, although some long-term Objectives are proposed where present environmental quality does not ensure maximum protection of designated uses.

2.1.2 THE MAIN STEM

Waste discharges enter the Main Stem primarily from landfill leachate seepage, agricultural runoff, forest products operations, stormwater outfalls, and combined sewer overflows. These have been summarized by Atwater (1980), Ferguson and Hall (1979), Singleton (1980), Swain (1980), Lawson et al. (1985), and Swain and Holms (1985).

The water movement in the lower Fraser River, below Chilliwack at low river flows and below Mission at high flows, is a function of both tides in the Strait of Georgia and of river discharge. The speed and the direction of the river flow depend on the stage of the tide outside the estuary. Tidal influence is particularly noticeable in river reaches below New Westminster. As in all tidal rivers, the outgoing ebb lasts longer than the incoming flood tide (Swain and Holms 1985).

An important feature affecting flow distribution in the river is the intrusion of dense saline water from the Strait of Georgia upstream into the Main Arm to New Westminster. The saline water is forced upstream in the form of a wedge by the rising tide, reducing the cross-sectional area for the outflowing river water at a given water level, causing the water level to rise (Swain and Holms 1985).

The Main Stem of the Fraser River has several uses designated for protection (Table 1). Generally, aquatic life is the most sensitive use relative to environmental conditions. The river water was "soft" which provided a moderate buffering capacity to acidic inputs, but was poorly buffered against alkaline inputs. Total metal levels in the river water, with the exception of copper and iron, generally met Provincial working Water Quality Criteria for the protection of aquatic life. Metal values in the water column higher than Provincial working Water Quality Criteria were generally associated with high suspended solids concentrations. For example, a value of 0.012 mg/L total copper coincided with a suspended solids level of 426 mg/L in the river. Metal values in the Main Stem (Swain and Holms 1985) between 1980 and 1982 were generally unchanged from those reported by Drinnan and Clark (1980).

Nutrient values from 1980 to 1982 were unchanged from those reported by Drinnan and Clark (1980) and are not a major concern in the Main Stem in terms of eutrophication potential. Natural turbidity in the water limits light penetration, thus reducing primary production. Dissolved oxygen levels from 1980 to 1982 were generally high (near saturation) in the Main Stem although monitoring did not take place in the sloughs or sidechannels where lower levels might be expected. Fecal coliform levels were high in the river water at the upper end of the Main Stem (near Kanaka Creek), with a median value of about 275 MPN/100 mL, a 90th percentile of 1300 MPN/ 100 mL, and a post-1979 maximum of 3500 MPN/ 100 mL (Swain and Holms 1985). Values in 1973, 1974, and 1975 at the Pattullo Bridge site had 90th percentiles of 6 700, 4 800, and 13 000 MPN/100mL, respectively (Churchland 1980). Fecal coliform levels are usually lowest during the summer months when stormwater runoff is at a minimum, and the sewage treatment plant effluents are disinfected.

Benthic organisms (invertebrates and leeches) sampled near Barnston Island had the highest aluminum and copper levels found during a 1985 survey of the estuary (Swain 1986). The number of results for benthic organisms is limited due to the large mass of organisms required for analysis. Barnston Island is a site thought to be relatively unaffected by discharges and has been used as a control site. Aluminum and copper in the sediments at this site were lower than at five other sampling sites. Overall, bioconcentration factors between benthic organisms and sediments indicated a possible relationship between the two compartments for cadmium, copper, and zinc. Higher copper and iron values were found in three of the seven composite benthic organism samples collected in 1985 from the Main Stem than were recorded for the same organisms in earlier surveys (Swain 1986). However, an adequate data base is not available to judge whether conditions might be deteriorating.

Fish from the Main Stem analyzed in a 1985 survey (Swain 1986) included a muscle tissue sample from a prickly sculpin collected near Sapperton Channel which had the highest chromium (1.72 µg/g dry weight) and mercury levels (1.36 µg/g wet weight) and second highest zinc level (43 µg/g dry weight) in muscle relative to other fish caught during the same survey. A Dolly Varden collected near Barnston Island was the only fish with a detectable nickel concentration (5.43 µg/g dry weight) in the liver (Swain 1986). The number of fish analyzed in the 1985 survey was insufficient to assess conditions in the estuary relative to past studies.

Concentrations of PCB's in sediments from both Main Stem sites sampled in 1985 (three replicates per site) exceeded the Water Quality Objective of 0.03 µg/g (dry weight) (Swain 1986). Concentrations of PCB's (0.5 µg/g wet weight) in three fish muscle samples were less than the Objective. Similarly, the Objective for chlorophenols in sediments (0.01 µg/g dry weight) was exceeded, but chlorophenol concentrations in fish muscle tissue in a peamouth chub, Dolly Varden, and prickly sculpin were less than the Objective of 0.1 µg/g (wet weight). These results, based on very limited data, suggest that although PCB's and chlorophenols are above background levels in sediments; however, these contaminants are not in evidence in

muscle of fish tested. Liver tissues were not analyzed. Achieving reduction in sediment levels of PCB's and chlorophenols will provide a further safety margin for fish. Levels of PCB's and chlorophenols in water, sediments, and biota are being monitored.

2.2 FRASER RIVER NORTH ARM

There are no tributaries with substantial flows to the North Arm of the Fraser River. The North Arm carries approximately 15% of the Main Stem flow at New Westminster.

Waste discharges into the North Arm include metal finishing plants, a paper recycling operation, lumber mills, a groundwood pulp and paper mill, food industry operations, and a large number of combined sewer overflows and stormwater discharges. These discharges have been summarized by Ferguson and Hall (1979), Cain and Swain (1980), Swain (1980), Singleton (1980), Swain (1983), and Swain and Holms (1985). Stormwater discharges from wood treatment facilities had not been included in previous monitoring. However, Wilson (presentation 2.17, Appendix) has reported that most treated lumber is stored uncovered, and that chlorophenate residues are leached or washed off the lumber during rainfall and can enter the river, along with runoff from contaminated ground. Preliminary data on chlorophenol concentrations in this stormwater indicate that most discharges are acutely toxic to salmonids.

Stormwater discharges, combined sewer overflows, and some industrial discharges are thought to affect several characteristics (e.g. fecal coliforms, copper, lead, zinc, chlorophenols) in the North Arm (Swain and Holms 1985). As well, Hall and Jacob (presentation 2.16, Appendix) reported levels of <0.002 to 15.2 µg/L of 2,3,4,6 tetrachlorophenol and <0.002 to 2.8 µg/L pentachlorophenol in water adjacent to stormwater outfalls near Mitchell Island. After seven days, leeches concentrated up to 2946 µg/g tetrachlorophenol and 846 µg/g pentachlorophenol.

The relative shallowness of the North Arm prevents the salt wedge from moving uptream to New Westminster (Swain and Holms 1985). Flow reversals in the river, which can occur in the lower reaches at low river flow and high tide, complicate the understanding of the impact of point source discharges on the river. Effluents are influenced by varying dilutions while contaminants can remain in the river for varying periods of time. The effects of tides on effluent dispersion have been studied. Four peaks in the concentration of an effluent in the river from a point discharge were predicted over a 24-hour period, each corresponding to slack water. At slack water conditions, effluent dilution is minimized with the decrease in river velocity. Occasional flow reversals can cause the same particle of water to pass a discharge point several times, thereby creating multiple doses of effluent at that point (Swain and Holms 1985).

The North Arm of the Fraser River has several uses designated for protection by the B.C. MoEP. These are aquatic life, wildlife, recreation, livestock, and irrigation. Water Quality Objectives established by the Province for several characteristics in the Main Stem also apply to the North Arm (Table 1).

The characteristics of North Arm water are similar to those of the Main Stem, i.e., moderate buffering to acidic inputs exist. High values for total metals were usually associated with seasonally high levels of suspended solids. Nutrients were not a concern, dissolved oxygen was high (near saturation) and fecal coliforms were high in samples taken from well-flushed main channel areas (Swain and Holms 1985).

Concentrations of total zinc (maximum 0.04 mg/L) in North Arm water samples in 1979 and 1980 were less than the established Water Quality Objectives of ≤0.05 mg/L as an average and 0.10 mg/L as a maximum. Elevated total copper levels (maximum 0.011 mg/L) present in the river in 1979 and 1980, likely originated from natural suspended sediment inputs upstream from the North Arm (Swain and Holms 1985). The Objectives to protect users of

the North Arm from the impacts of copper are in Table 1. Values of total copper measured in 1986 ranged from 0.002 mg/L to 0.004 mg/L, which were less than the Objectives (Walton and Swain unpublished data).

Water Quality Objectives have been established for lead in the North Arm (Table 1). Five values measured in 1986 ranged from 0.002 mg/L to 0.005 mg/L (Walton and Swain unpublished data), thus maximum values were lower than the Objective of 0.01 mg/L based on a very limited set of data.

Benthic organisms collected in 1985 showed apparent bioconcentration from sediments of barium, cadmium, copper, strontium, and zinc in the North Arm, and of cadmium, copper, and zinc in the Main Stem. The number of results for benthic organisms is limited due to the tissue mass of organisms required for analysis. A polychaete sample from McDonald Slough had the highest iron value (11 600 µg/g dry weight) of any of the benthic organisms collected in the 1985 survey (Swain 1986). PCB's were not detected in a composite samples of polychaetes or pelecypods, although chlorophenols were present in the sample of polychaetes from McDonald Slough. Levels of PCB's and chlorophenols in fish muscle samples were less than the Objective (Swain 1986) based on the analysis of five staghorn sculpins, one rainbow and one cutthroat trout.

Some fish muscle samples collected in 1980 from the North Arm had detectable chromium, lead, mercury, and zinc (Singleton 1983). However, other than a high mercury value in one sample (0.49 µg/g) and a high lead value in a second sample (0.34 µg/g), metal values were similar to those in biota in other reaches of the lower Fraser and the same or lower than values recorded in 1972/1973 (Singleton 1983).

The highest aluminum, chromium, copper, iron, molybdenum, and zinc concentrations in 1985 were found in fish (usually staghorn sculpins) from the North Arm (Swain 1986). The highest chlorophenol levels in 1985 were found in seven fish and one polychaete sample from the North Arm, although the Water Quality Objective of 0.1 µg/g (wet weight) was not exceeded. It

should be noted that a sufficient number of individuals was not collected to allow for a sound prediction of contamination in the entire fish population. The chlorophenol concentrations in fish muscle from a 1980 survey (Singleton 1983) showed that levels in some samples exceeded the Water Quality Objective.

Other organic contaminants measured in the 1980 survey of fish muscle tissue were phthalate esters and PAH's. Although insufficient data are available to compare differences statistically, phthalate ester levels in fish from the lower Fraser River were similar to those from upstream, less-industrialized areas (Singleton 1983). The only measurable PAH was fluoranthene. Liver tissue sampling should be considered in future programs.

Water Quality Objectives have been established for un-ionized ammonia (Table 1), which were met outside initial dilution zones of discharges, for nine samples collected in 1986 (Walton and Swain unpublished data).

Data from three sampling occasions in 1986 at three sites between New Westminster and the Oak Street Bridge indicated increases in suspended solids of 12 mg/L and 16 mg/L in a downstream direction between New Westminster and the Oak Street Bridge (Walton and Swain unpublished data) . On one occasion, values decreased 7 mg/L (Walton and Swain unpublished data). Such small changes could result from changes in river velocity or reflect sampling variability. All samples were collected on ebb tides. The maximum increase took place under dry weather conditions, when stormwater was not being discharged.

Fecal coliforms in the North Arm were as high as 4900 MPN/100 mL for three samples collected in November 1986; however, three samples collected in each of September and December 1986 were <2400 MPN/100 mL (Walton and Swain unpublished data). The Objectives for coliforms of ≤1000 MPN/100 mL as a geometric mean and 4000 MPN/100 mL as a maximum are not applicable at that time of year when irrigation is not a designated water use. The Objective for the maximum fecal coliform concentration was usually met at other times of the year.

2.3 FRASER RIVER MAIN ARM

Waste discharges which enter the Main Arm include a major primary treated municipal wastewater discharge from the Annacis Island sewage treatment plant (STP) and a smaller primary treated discharge from the Lulu Island STP. There are also wastewater discharges from metal finishing, chemical and concrete manufacturing, and food processing industries. These have been summarized by Cain and Swain (1980), Swain (1980), Singleton (1980), and Swain and Holms (1985). Jacob (presentation 2.26, Appendix) identified that the average daily loadings of most selected organic contaminants were from nine to twenty-eight times higher in effluent from the Annacis Island STP than at the Lulu Island STP, even though the flow ratio was only 7:1. The largest difference between treatment plants was for PAH's, probably due to stormwater which is a portion of the incoming sewage at the Annacis STP.

The Main Arm of the Fraser River carries 85% of the flow of the Main Stem at New Westminster. Tidal influences are pronounced in the Main Arm below New Westminster. An important feature affecting flow distribution in the river is the intrusion of dense saline water from the Strait of Georgia upstream to New Westminster. The saline water is forced upstream in the form of a wedge by the rising tide, reducing the cross-sectional area for the outflowing river water at a given water level, causing the water level to rise (Swain and Holms 1985).

Flow reversals in the river, which can occur in the lower reaches at low river flow and high tide, complicate the understanding of the impact of point source discharges on the river. Effluents experience varying dilutions and contaminants can remain in the river for varying periods of time. The effects of tides on effluent dispersion have been studied. Four peaks in the concentration of an effluent in the river from a point discharge were predicted over a 24-hour period, each corresponding to slack water. At slack water conditions, effluent dilution is minimized with the decrease in river velocity. Occasional flow reversals can also cause the

same particle of water to pass a discharge point several times, thereby creating multiple doses of effluent at that point (Swain and Holms 1985).

Waldichuk (presentation 2.14, Appendix) identified that the salt wedge can penetrate upstream in the Main Arm past Annacis Island, and into various sloughs and backwaters where it can be trapped in depressions for several weeks. This can result in dissolved oxygen depressions in the bottom layers, especially during summer. Birtwell et al. (presentation 2.19, Appendix) identified severe dissolved oxygen depletion in deep dredged pockets in Deas Slough opposite two marinas.

The water chemistry of the Main Arm was quite similar to that of the North Arm and Main Stem. However, total cadmium was detected more frequently between 1979 and 1980 in water in the Main Arm than in the North Arm, while total chromium values were considerably higher (e.g., 0.014 mg/L maximum) near Steveston Island than at the Pattullo Bridge on the Main Stem (e.g., 0.010 mg/L maximum) (Swain and Holms 1985).

Water uses designated for protection by the Province are presented in Table 1. Water Quality Objectives established for the Main Arm are similar to those for the Main Stem and the North Arm (Table 1). One Objective unique to the Main Arm and the Banks is that total residual chlorine should not exceed 0.002 mg/L. This Objective is in place to ensure that when disinfection occurs at the major sewage treatment plants, dechlorination effectively eliminates chlorine before discharge.

A 1980 survey of Fraser River fish from the Banks to its headwaters at Moose Lake concluded that many metal levels in fish muscle remained the same or declined when compared with a 1972 survey (Singleton 1983). Past elevated metals levels were attributed to man's activities, except for copper which was highest upstream from developed areas (Singleton 1983). The cause for this high upstream copper is unknown.

The following contaminants sampled in a limited number of organisms in 1985 were highest that year in the Main Arm compared to organisms from the other main reaches (Swain 1986): chromium and iron in one cutthroat trout liver and chromium in one composite sample of leeches from Annacis Channel; cadmium in one polychaete sample from Ewen Slough; lead in muscle from one Dolly Varden and copper and lead from a second cutthroat trout from Annacis Channel; lead in one composite pelecypod sample from Ewen Slough; mercury in the muscle of a cutthroat trout from Annacis Channel; and molybdenum in one composite pelecypod and one composite polychaete sample from Ewen Slough. Future studies should determine if such differences in levels between reaches are consistent over time. Chlorophenols and PCB's were not detected in the eight fish sampled from the Main Arm (Swain 1986).

Bioconcentration from sediments to benthic organisms was apparent for chromium in single composite leech and chironomid samples, nickel in one composite sample of leeches, and copper and zinc in the single composites of leeches, lampreys, oligochaetes, and chironomids (Swain 1986). All were collected from a site immediately north of Annacis Island. Bioconcentration was also apparent for strontium in Annacis Channel for all five benthic organisms sampled (Swain 1986). In Ewen Slough, bioconcentration from sediments to benthos appeared to occur for barium in a composite amphipod sample, and copper, strontium, and zinc in composites of both amphipods and polychaetes (Swain 1986). Bioconcentration of copper, lead, and zinc was apparent between sediments and benthic organisms in the North Arm and Main Stem. This indicates that these metals are possibly entering the food chain.

In the same 1985 survey, PCB's and chlorophenols were not detected in six sediment samples (three discrete samples at each of two sites) from the Main Arm (Swain 1986). Some differences were noted between total metals data for sediments from 1985 and those reported in 1980. These differences could be real or may be artifacts of sampling location or time of year. In the Main Arm, the most significant of these apparent changes occurred for copper and lead in sediments, which appeared to double between 1980 and 1985 (Swain 1986). This apparent doubling of values may be confirmed when

samples collected in 1987 for the B.C. Ministry of Environment and Parks by the Fraser River Harbour Commission have been analyzed.

Samples of water from the Main Arm collected during 1986 (n = 34) indicated the lowest dissolved oxygen level was 8.4 mg/L, which met the Objective (Moore unpublished; Greater Vancouver Regional District (GVRD) unpublished). For metals (n=31), the Objectives were achieved, except for one high (0.02 mg/L) total lead value (Moore unpublished; GVRD unpublished) which exceeded the Objective of a maximum concentration of 0.01 mg/L.

Chlorophenols were not detected (<0.2 µg/L) in the water column in four samples upstream and downstream from Annacis and Lulu STP's (Moore unpublished), while pH values were in the range for the Objectives (Moore unpublished; GVRD unpublished). Fecal coliform levels exceeded the Objective in only 2 of 30 measurements. Maximum values occurred in March 1986 (5000 MPN/100 mL; GVRD unpublished) and November 1986 (>24 000 MPN/100 mL; Moore unpublished) when the Objective for irrigation of ≤1000 MPN/100 mL as a geometric mean or 4000 MPN/100 mL as a maximum to protect irrigation waters did not apply.

2.4 STURGEON AND ROBERTS BANKS

The major point source discharge to Sturgeon Bank was the Iona STP discharge. On Roberts Bank the main discharges were the much smaller Tsawwassen ferry terminal and coalport sewage discharges. These have been summarized by Cain and Swain (1980) and Swain and Holms (1985). Non-point source discharges originated from the Roberts Bank coalport, loading ships, runoff from the B.C. ferry terminal and camping along the causeway. Water uses designated for protection and Water Quality Objectives prepared by the B.C. Ministry of Environment and Parks are in Table 1.

Rogers (presentation 2.18, Appendix) found that juvenile salmon exposed to the discharge from the Iona STP rapidly accumulated DDT, PCB's, PCP, and 2,3,4,6 tetrachlorophenol. Chapman *et al.* (presentation 2.8, Appendix) found the concentrations of organic contaminants in the effluent from the Iona STP to be highly variable on a monthly and yearly basis.

Fecal coliform Objectives of ≤200 MPN/100 mL as a geometric mean and ≤400 MPN/100 mL as a 90th percentile were not always achieved in the Wreck Beach area near Point Grey. The causes of these excursions have not been clearly identified, but possible sources are ditch discharges from the University Endowment Lands or the North Arm.

The other Water Quality Objectives (Table 1) were achieved in most areas except near the site of the Iona STP discharge. Chapman et al. (presentation 2.8, Appendix) noted that fecal coliforms were consistently higher in surface waters near the outfall from the Iona STP. A deep-sea outfall is presently being constructed to transport primary treated wastewater seaward from the Banks. After the completion of the deep-sea outfall, a survey will be conducted to determine whether the Objectives are achieved in all areas outside the initial dilution zone (100 m radius) of the new discharge point.

Monitoring near the site of the new outfall provided baseline information on the achievement of Objectives near this location. The GVRD undertook an intensive monitoring program of water, sediments, and biota near this site, prior to, and during construction, in 1986 and 1987. One program examined single sediment samples of chlorophenols in surface (0-15 cm) and near surface (15-30 cm) sediments along the outfall route at distances of 60, 150, 300, 450, and 600 metres from the end of the Iona jetty. The Objective for chlorophenols in sediments of 0.01 µg/g was met at distances up to 300 metres from the jetty, but exceeded at 300 metres and beyond, especially by tetrachlorophenol. The highest values were for tetrachlorophenol in both surface and near surface samples at 450 metres (0.049 and 0.064 µg/g, respectively) and 600 metres (0.05 and 0.08 µg/g, respectively). In surface samples at 300 metres from the jetty, 0.054 µg/g of tetrachlorophenol were measured.

A consultant for the GVRD conducted biological and water chemistry sampling at three sites on the Banks in 1986. These sites were located in the immediate receiving area for the proposed deep sea outfall (at a total

of 27 stations). Also included were two reference sites, one near the southern edge of Sturgeon Bank and the second in the middle of Roberts Bank. Dissolved oxygen levels ranged from 8.2 mg/L at 5 m above the bottom to 10.9 mg/L at 0.5 m below the water surface (EVS Consultants 1986), compared to the Objective of 9 mg/L as a minimum (Table 1). Fecal coliforms were always highest in surface waters (1600 MPN/100 mL) and lowest (<2 MPN/ 100 mL) in water 5 m above the bottom off Roberts Bank (EVS Consultants 1986). The Objective for fecal coliforms does not apply to marine areas other than to beaches. The maximum measured total ammonia level was 0.040 mg/L. The calculated un-ionized ammonia at this concentration was less than the Objective.

Several other water quality characteristics were measured during the same surveys (EVS Consultants 1986). Values for pH ranged from 7.46 at the surface to 8.0 at depth. Nonylphenol values ranged from <0.10 to 0.17 µg/L. Total copper values (maximum of 0.007 mg/L) exceeded the marine Criterion (0.003 mg/L). Maximum metals values occurred as often at the reference site in the middle of Roberts Bank, as at the proposed discharge site (EVS Consultants 1986); therefore the new discharge site reflects similar water quality to the reference site. This is important for future studies to determine if there is degradation from the discharge.

Chapman et al. (presentation 2.8, Appendix) in reference to these data noted that the water chemistry showed a similar high level of variability (except fecal coliforms) between the two sampling occasions and when compared to previous studies. Sediment quality monitoring showed a low level of variability between stations and when compared to previous studies.

Seven organic compounds (naphthalene, methylphenanthrene, dichlorobenzene, hexachlorobenzene, dibutylphthalate, diethylhexylphthalate, and DDE) and eight inorganic elements (Cd, Ag, Cr, Cu, Pb, Zn, As, Hg) were detected in sediments in the 1986 survey (EVS Consultants 1986). Concentrations of all organics, except phthalate esters, were within twice the detection limit (which varied with each compound). Dibutylphthalates ranged from 0.060 µg/g

dry weight to 0.399 µg/g dry weight, while diethylhexylphthalates ranged from 0.126 µg/g to 1.139 µg/g dry weight. Total silver and cadmium were below detection (<0.25 µg/g dry weight) in all sediment samples, while chromium ranged from 39.4 to 63.2 µg/g, copper from 15.4 to 43.9 µg/g, lead from 6.6 to 18.5 µg/g, zinc from 50.3 to 101.5 µg/g, arsenic from 6.3 to 11.2 µg/g, and mercury from 0.044 to 0.105 µg/g, dry weight.

In the same 1986 survey, mean values for six replicates of ten different species of biota were reported on a dry-weight basis (EVS Consultants 1986). The highest mean levels of inorganic compounds were found in livers from sockeye salmon (8 µg/g Cd and 761.5 µg/g Cu), claw muscle from crabs (309 µg/g Zn and 0.68 µg/g Hg), clams (9.4 µg/g Cr and 6.16 µg/g Pb), and from sea cucumbers (257 µg/g As). The highest levels of organic compounds were found in muscle and liver tissues from both small and large Rex sole. The highest levels of dibutylphthalate (0.51 µg/g) and diethylhexyl phthalate (1.09 µg/g) occurred in muscle, while the highest levels of hexachlorobenzene (0.169 µg/g), 2, 3, 4, 6 tetrachlorophenol (0.12 µg/g), pentachlorophenol (0.24 µg/g), nonylphenol (20.8 µg/g), and PCB's (1.55 µg/g) were present in livers. Chapman et al. (presentation 2.8, Appendix) in reference to these data suggested contaminant concentrations in specific organisms and tissues are highly variable with a high degree of annual variability for the same species and tissues.

An examination of various biota in 1986 showed the most common histopathological abnormalities in samples from the Banks were lesions in the gills and the presence of parasitic helminths in both English and Rex sole, and skin papillomas on Rex sole. They were believed to be natural rather than related to anthropogenic activity (EVS Consultants 1986); however, species subject to stress (e.g. water pollution) are thought to be more easily susceptible to disease. The most significant finding of the pathology is the 8% of liver lesions which are likely related to chemical exposures.

Surveys of contaminant levels in sediments and benthic fish and invertebrates were undertaken by Environmental Protection from 1984 to 1986

(Harding et al. in prep.). Total metals were high in sediments near the Iona STP discharge (examples: chromium, 84 µg/g; copper, 63 µg/g; lead, 29 µg/g; and zinc, 148 µg/g dry weight). In other areas of the Banks, values for the same metals were appreciably lower (chromium, ≈40 µg/g; copper, ≈10 µg/g; lead, ≈3 µg/g; and zinc, ≈60 µg/g dry weight). Polychlorinated biphenyls and chlorinated phenols in sediments were below detection at all intertidal stations, while PAH's were detected only at the Iona outfall at relatively low (ie., <2 to 44 ng/g dry weight) concentrations.

In the same survey, invertebrates living near the Iona outfall continued to have much higher metal levels than those found elsewhere on the Banks (Harding et al. in prep.).

The pattern of decreasing trace metal levels with distance from the Iona outfall was unchanged from a 1976 survey using the same sampling stations (L. Harding, presentation 2.19, Appendix). The deep sea outfall at Iona STP should allow the degraded intertidal zone to recover over time.

2.5 BOUNDARY BAY AND ITS TRIBUTARIES

Draft provisional Water Quality Objectives have been prepared by the B.C. Ministry of Environment and Parks for this area (Holms and Swain in prep.). Objectives are in Table 2 for Boundary Bay (including Semiahmoo Bay), the Little Campbell River, the Serpentine River and three of its tributaries (Mahood, Hyland, and Latimer Creeks), and the Nicomekl River and two of its tributaries (Murray and Anderson Creeks). Only Boundary and Semiahmoo Bays are in the FREMP study area.

Agricultural operations in the Little Campbell, Serpentine, and Nicomekl River watersheds are suspected to contribute large quantities of fecal coliforms, oxygen-consuming organic materials, and nutrients to these rivers. These nutrients cause excessive algal growths which, in association with oxygen-consuming material, result in large fluctuations in dissolved

oxygen. Duncan et al. (presentation 2.13, Appendix) showed preliminary results which indicated that the oxygen demand in agricultural runoff is the primary factor for low dissolved oxygen levels in the Serpentine River.

Numerous discharges of stormwater periodically increased suspended solids and lead levels in the watersheds. The first flush rain event caused specific conductivity and ammonia in agricultural ditches to decrease but to increase in the Serpentine River (Duncan et al., presentation 2.13, Appendix). As well, phosphorus decreased in both the ditches and the river, while nitrite and nitrate levels increased in both.

The Little Campbell River exhibited relatively low metal and ammonia values, moderate to low buffering capacity to acidic discharges, and had moderately soft water. Nitrate and phosphorus concentrations were elevated during periods of low flow and high temperature. Dissolved oxygen values were periodically very low (2.7 mg/L). Bacteriological quality, in terms of fecal coliform concentrations, was generally poor throughout the system. The proposed long-term Objectives for fecal coliforms (≤100 MPN/ 100 mL 90th percentile) and dissolved oxygen (8.0 mg/L minimum) were not usually achieved (Table 2). Although adequate measurements were not made, it is unlikely that the chlorophyll-a Objective (≤50 mg/m^2) was achieved. The other Objectives were usually achieved.

The pH of the Serpentine River can vary appreciably, with values near the headwaters ranging from 6.7 to 9.3, and those further downstream ranging from 3.8 to 7.7 (Holms and Swain in prep.). Alkalinity values were from moderate to low, while the water was "soft". Some high total metal values (maximum values in parentheses) were documented for aluminum (1.39 mg/L near the headwaters), copper (0.03 mg/L near the mouth), lead (0.044 mg/L near the headwaters), iron (33.4 mg/L in Serpentine fen), manganese (0.46 mg/L near the mouth), and zinc (0.24 mg/L in Serpentine fen) (Holms and Swain in prep.). These values were thought to be associated with high suspended sediment levels. Algal blooms may have been caused by elevated phosphorus levels. Ammonia and nitrite levels were thought to be of no concern. Large

variations occurred in dissolved oxygen (1.1 to 17.6 mg/L) and percent saturation values (9.7% to 279%), probably due to algal production and respiration and the presence of oxygen-consuming organic material. Duncan et al., (presentation 2.13, Appendix) found high oxygen production rates in bottom sediments in the Serpentine River prior to the first flush of stormwater. Fecal coliform values were too high to meet the long-term Objective of ≤100 MPN/100 mL as a 90th percentile. Dissolved solids reflected the influence of saltwater intrusion near the mouth, but were not so high as to restrict any water uses in the upper reaches (Holms and Swain in prep.).

As is the case for the Little Campbell River, the proposed long-term Objectives for the Serpentine River for fecal coliforms and dissolved oxygen were not usually achieved. It was unlikely that the Objective for chlorophyll-a was achieved. However, most of the other proposed Objectives usually were achieved.

The pH in the Nicomekl River basin was naturally high (>7.5), and the water was well buffered to acidic inputs (Holms and Swain in prep.). Some high values of certain elements (total aluminum to 0.77 mg/L, 1.3 mg/L dissolved boron near the mouth, 5.5 mg/L total iron, and 0.13 mg/L total zinc) were recorded, but these were likely associated with suspended sediments (Holms and Swain in prep.). High lead values (maximum 0.012 mg/L) may have originated from stormwater discharges. Total ammonia and nitrite values met the proposed Objectives. High levels of phosphorus and the presence of oxygen-consuming organic material were believed to cause low dissolved oxygen levels (0.8 mg/L minimum) and wide fluctuations in percent saturation values (8.8% to 264%). These low oxygen levels and fluctuating percent saturation values were not as pronounced in Murray and Anderson Creeks as in the Nicomekl River. High fecal coliform levels did not meet the proposed long-term Objective of ≤100 MPN/100 mL as a 90th percentile. High levels of dissolved solids near the mouth of the Nicomekl River reflected salt water intrusion. Except for the long-term Objectives, the remaining proposed Objectives were usually achieved (Holms and Swain in prep.).

Water quality in Boundary Bay was generally consistent for the period 1980 to 1982 (Holms and Swain in prep.). Data for pH, nutrients, and most metals met the MoEP working Criteria to protect marine aquatic life. Values for total copper, lead, mercury, and zinc occasionally exceeded MoEP working Criteria. These elevated levels may be explained by fluctuations in natural background levels in Boundary Bay, (i.e., sediments being resuspended), from stormwater runoff from the City of White Rock, or stormwater runoff and/or treated domestic sewage discharges from Blaine and Drayton Harbour (Holms and Swain in prep.). Dissolved oxygen levels usually met the proposed short-term Water Quality Objective, but not the proposed long-term Objective (Table 2). Levels of fecal coliforms were too high to allow the harvesting of shellfish, but were low enough to allow use of the Bay for swimming. Thus, the proposed bathing beach Objective (≤200 MPN/100 mL geometric mean, ≤400 MPN/100 mL 90th percentile) was usually achieved, but the long-term Objective to allow shellfish harvesting (≤14 MPN/100 mL median, ≤43 MPN/100 mL 90th percentile) was not (Holms and Swain in prep.).

A procedure is being proposed in the Water Quality Plan for action where a Water Quality Objective is frequently exceeded. The procedure will require the Standing Committee to advise the appropriate FREMP Activity Work Group that a particular Objective is not being achieved, requesting that appropriate action be taken, if possible. This process will not preclude established agency enforcement procedures.

3. WORK GROUP FINDINGS

Three work groups were formed at the February 1987 workshop sponsored by FREMP to consider five questions and review the status of water quality in the Fraser River Estuary. The work groups were composed of the members identified in the Appendix.

The major findings of the work groups are summarized below. The opinions expressed were not necessarily shared by all groups or individuals within a group.

3.1 SUMMARY OF QUESTIONS AND RESPONSES

3.1.1 WHAT IS THE STATUS OF WATER QUALITY IN THE FRASER RIVER ESTUARY BY AREA (i.e., Main Stem, North Arm, Main Arm, Sidechannels, Sloughs, Banks, and Boundary Bay)?

The conditions of the various areas of the estuary are different. The most seriously degraded area is the North Arm, where the flow can be low and a number of industrial operations are situated, including metal finishing, sawmills, and pulp and paper. Conditions in the Main Stem are not thought to be significantly degraded. The Main Arm is probably intermediate between the Main Stem and the North Arm in terms of environmental quality.

Other problem areas include sidechannels and sloughs, the majority of which exhibit periodic low dissolved oxygen concentrations, and the Boundary Bay tributaries. Boundary Bay remains closed to shellfish harvesting due to coliform levels. The condition of Sturgeon and Roberts Banks is generally good, with the exception of Sturgeon Bank near the Iona STP outfall where extensive degradation is evident.

3.1.2 IS THE CURRENT INFORMATION ON THE FRASER SUFFICIENT TO ANSWER QUESTION 3.1.1 (i.e., What are the data gaps?)?

The information currently available is not sufficient to define the status of the estuary in terms of statistical significance, but is adequate for evaluating the relative condition of the different areas.

Major data gaps include:

- the effects of specific contaminants on aquatic organisms including acute toxicity, chronic effects, bioaccumulation; on individuals as well as populations.

- the toxicity and bioavailability of sediment-associated contaminants.

- an adequate knowledge of water movement, sedimentation, and salt water intrusion and effects on contaminant flux.

- the degree of public health risk from existing levels of bacteriological contamination of the estuary.

- knowledge on monitoring techniques for large rivers.

- resource mapping of the estuary.

- inputs of pollutants from upstream.

- information on the quality and volume of non-point discharges.

- information on contaminants and other water quality conditions in sloughs and sidechannels.

3.1.3 WHAT ARE THE ISSUES, IN ORDER OF PRIORITY, THAT SHOULD BE ADDRESSED IN EACH AREA?

Main Stem and Tributaries

In the Coquitlam River (although not within the FREMP study area) there are increased sediment loads from gravel-washing operations and reduced salmon runs. The Brunette River receives urban runoff and has experienced fish kills and a chlorophenol spill.

North Arm

Issues include low dissolved oxygen in the sloughs, general habitat losses and contamination by metals and organic compounds (e.g., chlorophenols and PCB's), combined sewer overflows along the north shore, bacteriological contamination, the effects of log booming, wood waste accumulation and leachates, and metal losses from shipyards and metal finishing operations.

Main Arm

Habitat loss as well as organic contamination from municipal discharges and other sources are the major problems in the Main Arm. Compounds of concern in discharges include di- and trichlorophenols, non-chlorinated phenols, PAH's, and ammonia. Elevated levels of fecal coliforms are usually found in the river in winter. Other problems include potential cumulative effects from multiple point sources, freighters, and other boating activities, and pesticides from agriculture. Contaminants carried in the Fraser plume may affect U.S. waters.

Sloughs and Sidechannels

The sloughs and sidechannels are the most important areas for fish and aquatic life in the estuary. Problems include periodic low dissolved oxygen; habitat loss; contamination by organics, metals, and bacteria; unidentified contaminant sources; sedimentation and resuspension of contaminants.

Sturgeon and Roberts Banks

Low dissolved oxygen, habitat loss, and contamination by metals and organic compounds are the major problems on Roberts and Sturgeon Banks. Specific perceived problems on the Banks include increasing dioxin concentrations in eggs of blue herons, the need for protection from development,

and the potential for increased metals availability at the salt wedge-freshwater interface.

Boundary Bay and Tributaries

Low dissolved oxygen, and possibly pesticides and other contaminants may cause the frequent fish kills in the Serpentine River. Boundary Bay has bacteriological contamination which precludes commercial shellfishing.

3.1.4 WHAT MECHANISM SHOULD BE USED TO ADDRESS THESE ISSUE(S)?

The responses of the work groups included the following: a) utilize current policy, legislation, and enforcement techniques; b) provide for more public information and involvement; c) implement source control programs and improve effluent treatment; d) locate and design industrial facilities to minimize environmental impacts; e) increase education of public and industry; f) coordinate and fund the efforts of the research community, create a research advisory committee; g) generate more political will and improve communication with politicians.

3.1.5 WHAT ARE THE POTENTIAL MEANS OF OBTAINING FUNDS FOR FRASER RIVER RESEARCH?

Use public opinion (through polls and plebiscites) to influence the politicians and make them aware of the long term economic benefits of pollution control, including job creation. Funds could also be raised through a cigarette or toilet paper tax, through an environmental lottery or charity which would provide tax receipts for donations. Scientists may be able to convince administrators to increase funding by pointing out that, if adequate environmental information is not collected, the cost of reversing the damage to the environment will far exceed the cost of the program.

3.2 FINDINGS OF THE PLENARY SESSION

1. The workshop should be opened to representatives of industry, the public and other users of the river so that a wider range of viewpoint could be expressed. If industry were better to appreciate the value of protecting water quality, more funds might become available for the management program. An "open" workshop could also act as a forum for public education.

2. Some participants suggested that the conference be restructured so that each session has a keynote speaker on a particular topic followed by a discussion. Other participants favoured the existing format of short technical presentations followed by a question period.

4. CONCLUSIONS OF THE STANDING COMMITTEE ON FRASER RIVER ESTUARY WATER QUALITY

Past monitoring in the Fraser River Estuary has been sporadic, and not all areas have been surveyed to provide an adequate description of spatial/temporal variation. The 1984 monitoring program (Working Committee on Fraser River Estuary Monitoring 1984) and present monitoring being conducted to check achievement of Water Quality Objectives are a starting point for comprehensive monitoring in the estuary. An updated coordinated monitoring program will be proposed in the Water Quality Plan. These activities will make future reports on estuary status easier to prepare and more meaningful.

The Standing Committee on the FREMP Water Quality Plan considers the overall water quality of the Fraser River Estuary study area to be largely a function of high river flows which flush and assimilate contaminants from the system and minimize the impacts of treated and untreated discharges. Localized, poorly flushed sidechannels and sloughs may be degraded. The data indicate that the water quality in the main channels is similar to that reported in 1979. It is recognized that to describe the environmental status of the lower Fraser River and Estuary in one word such as good or fair is not very informative. To be more objective, the use of numerical values for certain characteristics which are of concern to different water users (i.e., Water Quality Objectives) is generally accepted. In the main river channels, the Water Quality Objectives are usually achieved outside most initial dilution zones as well as inside large portions of several other initial dilution zones. However, there is no cause for complacency since toxic and persistent contaminants have been identified in compartments of the aquatic ecosystem at different locations in the estuary. Examples of these problems have been described in the workshop presentations.

An overview of findings of the work groups from the February 1987 FREMP workshop indicated that the Main Stem of the Fraser River exhibited the best water quality of the three reaches. This was due to high flows and relatively fewer discharges. Of the three river reaches, the North Arm

has the greatest vulnerability to contamination, due to low river flows and relatively high discharge volumes. Contaminants of concern in such discharges include chlorophenols, copper, lead, zinc, and fecal coliforms.

The Standing Committee supports ongoing agency investigations of contaminants in effluents discharged to the lower Fraser River. Initiatives to identify problems related to the use of chlorophenols and other contaminants in the estuary are supported. Research activities undertaken by universities and government agencies are also essential to link the measured levels of contamination with effects on aquatic life and fish production.

The Iona STP discharge will be moved from Sturgeon Bank where significant impacts on sediment and biota have been documented. A multiport diffuser discharging at depth in salt water will improve dilution and dispersion of the effluent. This has not compromised the possible implementation of secondary treatment at the Iona STP in the future. The Committee recognizes the importance of the pre- and post discharge monitoring program being conducted, so that changes in water quality can be determined.

Sloughs and backchannels exhibit depressed dissolved oxygen levels periodically. It is recommended that additional site-specific studies be undertaken in important habitat areas, as priorized by DFO and MoEP (Recreational Fisheries Branch), in order to document further fish usage and water quality conditions.

Boundary Bay often exhibits bacteriological contamination which has precluded shellfish harvesting for the last two decades. In the tributaries, dissolved oxygen levels are seasonally depressed and nutrient concentrations are excessive. Runoff from agricultural lands contributes to the nutrient and oxygen problems. Site-specific studies should be undertaken, initially on the Serpentine River, with the view to documenting suspected sources. Corrective actions should then be initiated, with the cooperation of the B. C. Ministry of Agriculture and Fisheries at sources of agricultural water quality problems.

The Water Quality Objectives published or under development by MoEP are a starting point for an assessment of the status of water quality in the estuary and a basis for the Water Quality Plan. A mechanism will be proposed in the Water Quality Plan to update the existing Objectives, as needed, and to propose new Objectives.

Under the B.C. Waste Management Act, municipal governments are provided the opportunity to develop "waste management plans" for comprehensive management of solid and liquid municipal wastes. The efforts of the GVRD to develop a Liquid Waste Management Plan are supported by the FREMP Standing Committee, and continued liaison is occuring with the GVRD.

A number of major data gaps have been identified in the Appendix. These will be reviewed by the Standing Committee and projects will be proposed to address data gaps in the Water Quality Plan.

Funding opportunities for monitoring programs are discussed in Section 3.1.5. These opportunities should be reviewed by the respective agencies for applicability to the Fraser River Estuary Monitoring Program.

REFERENCES CITED

Atwater, J. 1980. Fraser River Estuary Study, Water Quality, Impact of Landfills. Vancouver, B. C. April 1980.

Canadian Council of Resource and Environment Ministers (CCREM). 1987. Canadian Water Quality Guidelines. Ottawa, Canada. March 1987.

Churchland, L.M. 1980. Fraser River Estuary Study, Water Quality, Microbial Water Quality, 1970-1977. Vancouver, B.C. January, 1980.

Cain, R.T. and L.G. Swain. 1980. Fraser River Estuary Study, Water Quality, Municipal Effluents. Victoria, B. C. December 1980.

Drinnan, R.W. and M.J.R. Clark. 1980. Fraser River Estuary Study, Water Quality, Water Chemistry, 1970-1978. Victoria, B. C. December 1980.

EVS Consultants. 1986. Interim Report. Environmental Monitoring 1986, Iona Deep Sea Outfall Project. Vancouver, B. C. December 1986.

Ferguson, K.D. and K.J. Hall. 1979. Fraser River Estuary Study, Water Quality, Stormwater Discharges. Vancouver, B. C. December 1979.

Garrett, C.L., L.A. MacLeod, and H.J. Sneedon. 1980. Environment Canada, Environmental Protection Service. Mercury in the British Columbia and Yukon Environments--Summary of Data to January 1, 1979. March 1980.

Greater Vancouver Regional District. Unpublished Monitoring Data For 1986.

Harding, L., M. Pomeroy, A. Colodey, and L.L. Grooms. Fraser River Estuary Marine Environmental Monitoring Results 1984-1986. (In prep.).

Holms, G.B. and L.G. Swain. B.C. Ministry of Environment and Parks. Fraser-Delta Area, Boundary Bay and Its Tributaries, Water Quality Assessment and Objectives. (In prep.).

Lawson, E.M., G.B. Mitchell, and D.G. Walton. 1985. B.C. Ministry of Environment and Parks. Stormwater Monitoring of an Industrial Catchment Basin Located in Burnaby, British Columbia. Vancouver, B. C. March 1985.

Ministry of Environment and Parks. 1986. Principles For Preparing Water Quality Objectives in British Columbia. Victoria, B. C. September 1986.

Moore, B. Waste Management, Lower Mainland Region, Surrey. Unpublished Monitoring Data For 1986.

Nordin, R.N. and L.W. Pommen. 1986. B.C. Ministry of Environment and Parks. Water Quality Criteria For Nitrogen (Nitrate, Nitrite, and Ammonia). Victoria, B. C. November, 1986.

Singleton, H.J. 1980. Fraser River Estuary Study, Water Quality, Acute Toxicity of Effluents. Victoria, B. C. December, 1980.

Singleton, H.J. 1983. B.C. Ministry of Environment. Trace Metals and Selected Organic Contaminants in Fraser River Fish. MoE Technical Report 2. Victoria, B. C. April 1983.

Standing Committee on the Fraser River Estuary Water Quality Plan. (in prep.). Fraser River Estuary Management Program. Water Quality Plan - 1988.

Swain, L.G. 1980. Fraser River Estuary Study, Water Quality, Industrial Effluents. Victoria, B. C. December, 1980.

Swain, L.G. 1983. B.C. Ministry of Environment. Stormwater Monitoring of a Residential Catchment Area, Vancouver, B. C. Victoria, B. C. June 1983.

Swain, L.G. and G.B. Holms. 1985. B.C. Ministry of Environment. Fraser-Delta Area, Fraser River Sub-basin From Kanaka Creek to the Mouth, Water Quality Assessment and Objectives. Victoria, B. C. November, 1985.

Swain, L.G. 1986. B.C. Ministry of Environment and Parks. A 1985 Survey of Metals, PCB's and Chlorophenols in the Sediments, Benthic Organisms and Fish of the Lower Fraser River. Victoria, B. C. June 1986.

Swain, L.G. B.C. Ministry of Environment and Parks. Coquitlam-Pitt River Area, Tributaries to the Fraser River Along the North Shore, Water Quality Assessment and Objectives. (In Prep.).

Walton, D. Waste Management Lower Mainland Region and L. Swain, Water Management Branch, Victoria. Unpublished Monitoring Data for 1986.

Water Quality Work Group. 1979. Fraser River Estuary Study, Water Quality, Summary Report of the Water Quality Work Group. Victoria, B. C. December 1979.

Working Committee on Fraser River Estuary Monitoring. 1984. Fraser River Estuary Monitoring, A Recommended Approach.

GLOSSARY OF TERMS

Absorption	The incorporation of a substance into the body of another (cf. sorption).
Acute toxicity	A pronounced effect (severe biological harm or death) produced in an organism by a substance or mixture of substances within a short period of time (usually 96 hours or less) after exposure.
Adsorption	The attachment of a substance on the surface of another (cf. sorption).
Aerobic	Denotes the presence of gaseous or dissolved oxygen (cf. anaerobic).
Algae	A group of simple chlorophyll-containing lower plants, mostly aquatic; although most are microscopic, some forms reach extremely large sizes.
Algal bloom	A bloom of algae occurs when their growth is so rapid that they become numerous enough to colour a body of water.
Amphipoda	Order of Crustacea, including freshwater shrimp.
Ambient	Refers to conditions in the surrounding environment.
Anadromous	Ascending from the sea to freshwater for spawning at certain seasons.
Anaerobe	An organism that can only exist in the absence or near absence of gaseous or dissolved oxygen.
Anaerobic	Denotes the absence of gaseous or dissolved oxygen.
Anion	A negatively charged ion.
Anthropogenic	Relates to, or involves, the impact of man.
Aromatic Compound	A general term that includes the "hydrocarbons" of the benzene series.
Benthic Organism (Benthos)	Any organism that lives in or on the bottom of a waterbody or in the sediment thereof.

Bioaccumulation	The uptake, retention, and concentration above background levels of environmental substances by an organism from its environment.
Bioassay	Quantitative estimation of biologically active substances by the amount of their actions in standardized conditions on living organisms.
Biomagnification	The increase of a substance (contaminant) in a food web such that the organisms eventually contain higher concentrations of the substance than their food sources (cf. bioaccumulation).
Biota	Living organisms including bacteria, plants, and animals.
Buffer	A compound or solution capable of resisting a change in pH.
Carcinogen	A substance capable of causing cancer.
Cation	A positively charged ion.
Chlorophenols	Broad spectrum pesticides produced when phenol rings have a number of chlorine atoms attached. Used in wood processing to prevent discolouration by fungus.
Chlorophyll-a	Green pigment found in all plants except fungi and a few flowering plants and essential to photosynthesis.
Chronic toxicity	A long-term toxic effect produced in an organism by a substance or mixture of substances (e.g. toxin).
Combined Sewer Overflow	A point in a sewage collection system where domestic sewage mixed in varying proportions with stormwater overflows to a receiving water body.
Contaminant	A substance that infects by contact or association.
Copepoda	Subclass of Crustacea; small aquatic invertebrates that are food for fish.
Designated Water Use	A water use that is to be protected at a specific location.
Diffuser	A structure composed of several components, placed at the end of an outfall pipe, which is designed to spread the effluent widely so as to improve dilution.
Disinfection	The process of destroying microorganisms in water by the application of a chemical agent (disinfectant), such as chlorine.

Dissolved Metals	Metals in solution in a liquid.
Estuary	The lower end of a river where the tide meets a river current.
Eutrophication	The process of increasing the nutrient content of natural waters, so that biomass productivity is increased.
Food chain	The transfer of food energy from producers through a series of consumers.
Food web	A series of interconnecting food chains.
Fraser River Estuary	The area of joint social, economic and environmental concerns for the purposes of the FREMP Agreement, means in general, the land and water outside the boundary of the dykes and between Kanaka Creek and the outlet of Pitt Lake in the east, the estuary drop off in the west, Point Grey to the north and the international boundary to the south, including Boundary Bay and Semiahmoo Bay.
Geometric mean	The nth root of the product of "n" observations.
Habitat	Place with a particular kind of environment inhabited by organisms.
Heavy metals	Metallic elements of high atomic weight (e.g. copper, lead, etc.) typically with specific gravities greater than 5.
Hepatic	Adjective. Of the liver.
Initial Dilution Zone	Areas adjacent to a wastewater discharge wherein Water Quality Objectives (except those in fish) do not apply.
Invertebrate	Organism without a backbone.
Larvae	The pre-adult form in which some animals hatch from the egg.
Metalloid	Resembling a metal, or having chemical properties similar to metals.
Methylation	The process whereby a compound is modified chemically (often through bacterial action) by the replacement of a hydrogen atom by a methyl group (CH_3).

Micrograms per litre (µg/L)	One one-thousandth of one milligram per litre.
Milligrams per litre (mg/L)	A concentration unit of chemical constituents in solution; the weight of solute (substance) per unit volume of solvent (water).
Mollusca	Major group of mostly aquatic animals which are soft bodied, often with a hard shell e.g., clams, bivalves, snail, octopus, squid.
Most Probable Number (MPN)	The statistically determined number that represents the number of individual bacteria most likely to be present in a given sample.
Muscle	Tissue consisting of cells which are highly contractile. Most of edible parts of animals (flesh) is muscle.
Native state	Elemental state, or as the pure metal for metallic elements.
Nutrient	Substance (element or compound) necessary for the growth and development of plants and animals.
Oligochaetes	Freshwater worms. Cf. polychaetes.
Oligotrophic	Waters with a small supply of nutrients and hence low primary production.
Organic Contaminant	Organic chemicals which commonly are toxic, persistent, and mobile in the environment.
Pathogenic	Giving origin to, or resulting in, disease or death (pathogenic organisms and pathogens).
Pelecypoda	Bivalves, class of aquatic molluscs with bivalve shells.
pH	Negative of the logarithm (base 10) of the hydrogen-ion concentration. Quantitative expression for acidity or alkalinity of solution. Scale ranges from 0 to 14, pH 7 is neutral; less than 7 is acid; more than 7 is alkaline.
Photosynthesis	The process by which the chlorophyll-bearing cells of green plants, in the presence of light, convert carbon dioxide and water into sugar (an organic compound) with the evolution of oxygen.

Physiological	Characteristic of, or appropriate to, an organism's healthy or normal functioning.
Phytoplankton	The plant portion (phyto-) of the free-water community (plankton).
Plume	A portion of a waterbody which is distinguishable from the remainder because it is not completely mixed and its characteristics are measurably different.
Polychaetes	Marine worms including bristleworms, fanworms. Cf. oligochaetes.
Polychlorinated Biphenyl (PCB)	Scientific name for man-made liquid chemicals that are stable, non-corroding, fire resistant, and relatively non-biodegradable. Once used in electrical transformers because of these properties.
Primary Sewage Treatment	Removal of settleable solids through filtering, screening and/or settling.
Pristine	Describes a natural system (e.g., water) that has not been affected by anthropogenic (man-induced) pollution.
Raw water	Natural water-either surface or groundwater - that has not been treated or sterilized.
Saline	Waters having salt concentrations approaching that of seawater.
Salmonid	Fish of the family Salmonidae; including trout, salmon, char.
Secondary Sewage Treatment	Includes primary treatment and provides conditions for the biological oxidation of organic wastes.
Sidechannel	A slow moving body of water usually with two ends open to the main waterbody.
Slough	A slow moving body of water usually with the end open to the main waterbody.
Sorption	A general term for the process of absorption or adsorption. It is often used to denote the occurrence of both absorption and adsorption.
Spatial	Of or relating to space.
Sublethal	Involves an effect below the level that causes death.

Synergism	Combined activity such that the effect is either the additive of separate effects or greater than the sum of the separate effects.
Temporal	Of, or relating to time.
Tertiary Sewage Treatment	A third step in sewage treatment usually directed at greatly increasing the removal efficiency of nutrients.
Total Metal	A measure of metals in the dissolved state and those sorbed to particulate matter in suspension.
Toxic	Pertaining to, due to, or of the nature of, a poison, thus toxicity; the quality of being poisonous.
Trace element	A chemical element found naturally, or required by living organisms, in extremely small quantities (micronutrient).
Trace	A concentration that is below the detection limit of the standard chemical methods used.
Water-associated	Water is only one of the important means of transmission.
Water-borne	Water is the only or the principal means of transmission.
Water Quality Criteria	Numerical value(s) for a physical, chemical, or biological characteristic of water, biota, or sediment which must not be exceeded to prevent specified detrimental effects from occurring to water use.
Water Quality Guideline	Numerical concentration or narrative statement recommended to support and maintain a designated water use.
Water Quality Objective	A Water Quality Criterion or Guideline adapted to protect the most sensitive designated use at a specific location with an adequate degree of safety, taking local circumstances into account.

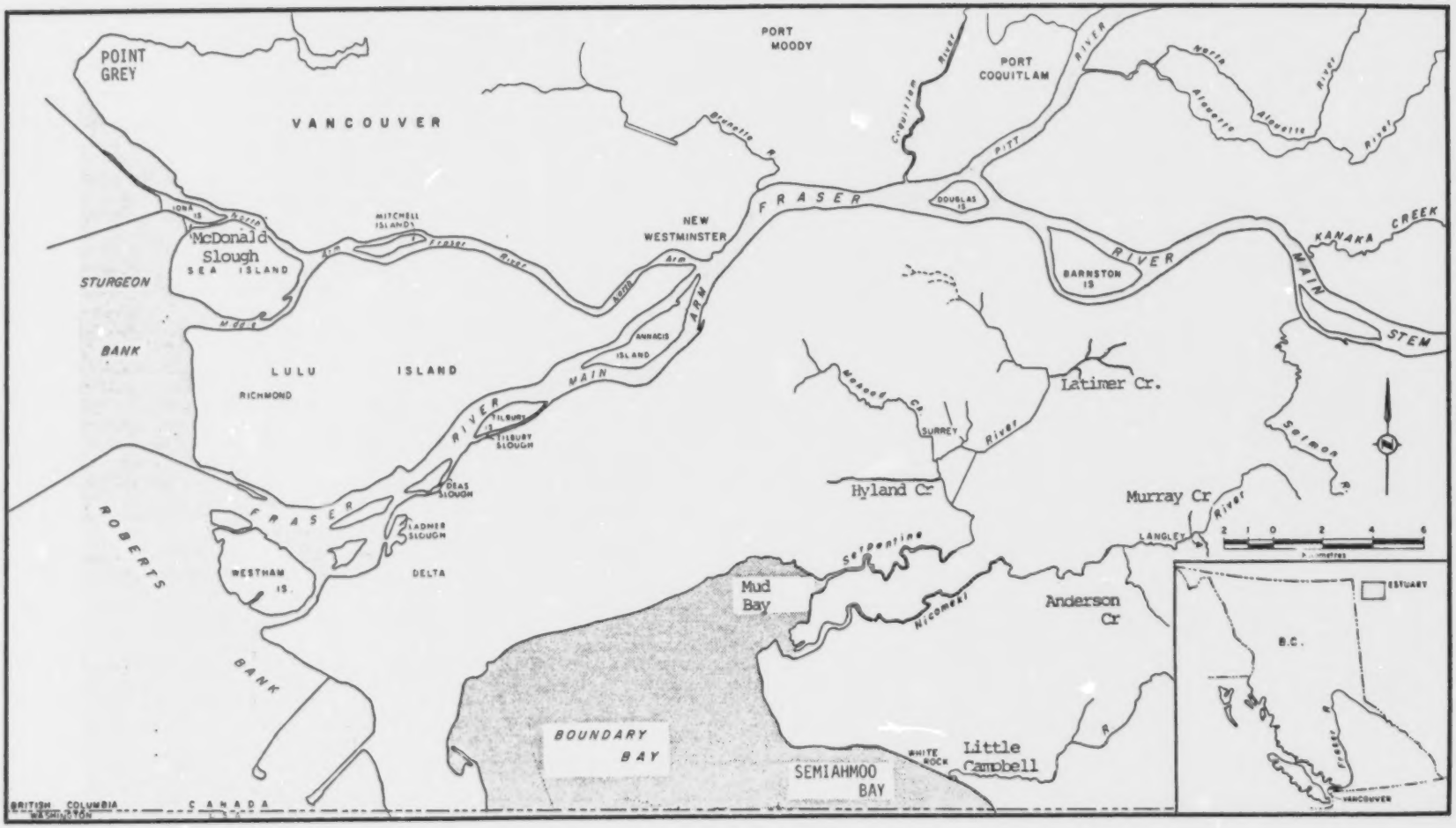

FIGURE 1 : THE FRASER RIVER ESTUARY

TABLE 1
PROVISIONAL WATER QUALITY OBJECTIVES FOR THE FRASER RIVER SUB-BASIN FROM KANAKA CREEK TO THE MOUTH
(PREPARED AND ISSUED BY B.C. MINISTRY OF ENVIRONMENT)

WATER BODIES	FRASER RIVER			STURGEON AND ROBERTS BANKS
	MAIN STEM	NORTH AND MIDDLE ARMS	MAIN ARM	
Designated Water Uses	Aquatic life, wildlife, recreation, livestock, irrigation			Aquatic life, wildlife, recreation
Fecal Coliforms[1]	≤1 000 MPN/100 mL geometric mean April - October 4 000 MPN/100 mL maximum April - October			≤200 MPN/100 mL geometric mean and ≤400 MPN/100 mL 90th percentile, at bathing beaches from June through August
Suspended Solids[2]	not applicable	10 mg/L maximum increase (upstream ≤100 mg/L) 10% maximum increase (upstream ≥100 mg/L)	not applicable	
Total Chlorine Residual[3]	not applicable		0.002 mg/L maximum	
Un-ionized Ammonia -N [4]	not applicable	0.03 mg/L maximum, ≤0.007 mg/L average		
Dissolved Oxygen	7.75 mg/L minimum			9 mg/L minimum
pH [5]	6.5 - 8.5			not applicable
Total Copper[6]	not applicable	For hardness ≥ 35 mg/L: 0.006 mg/L maximum, ≤0.004 mg/L average or 20% maximum increase, whichever is greater For hardness < 35 mg/L: 0.004 mg/L maximum, ≤0.003 mg/L average or 20% maximum increase, whichever is greater		not applicable
Total Lead[6]	not applicable	0.010 mg/L maximum ≤0.003 mg/L average		not applicable
Total Zinc [6]	not applicable	≤0.05 mg/L average 0.10 mg/L maximum		not applicable
Chlorophenols[4,7,8]	0.01 µg/g (dry weight) maximum in bottom surface sediments 0.1 µg/g (wet weight) maximum in fish muscle 0.2 µg/L maximum in water			0.01 µg/g (dry weight) maximum in bottom surface sediments
PCB's [7,8,9]	0.03 µg/g (dry weight) maximum in bottom surface sediments 0.5 µg/g (wet weight) maximum in fish muscle			not applicable

TABLE 1 (Continued)
PROVISIONAL WATER QUALITY OBJECTIVES

Note: The objectives apply to discrete samples from all parts of the waterbodies, except from initial dilution zones of effluents. These excluded initial dilution zones in the Fraser River are defined as extending up to 100 m downstream (or upstream at times of tide reversal) from a discharge, and occupying no more than 25% of the stream width around the discharge point, from the bed of the stream to the surface. These excluded initial dilution zones in marine waters are defined as extending up to 100 m horizontally in all directions, but not to exceed 25% of the width of the waterbody. This exclusion does not apply to objectives for fish as noted in 8 below. The words "not applicable" indicate that a particular characteristic will likely not be affected by man's activities in that waterbody or a reach of the waterbody.

[1] The geometric mean and the 90th percentile are calculated from at least five weekly samples taken in a period of 30 days. The recreation objective (200-400/100 mL) applies during the recreation season and the irrigation objective (1 000 - 4 000/100mL) applies during the irrigation season.

[2] The increase (in mg/L, or %) is over levels measured at a site upstream from a discharge or series of discharges and as close to them as possible, and applies to downstream levels.

[3] Since the objective is less than the minimum detectable concentration, it will be necessary to estimate the receiving water concentration using effluent load and stream flow. The objective applies only if sewage effluent is chlorinated.

[4] The average is calculated from at least five weekly samples taken in a period of 30 days.

[5] Measurements can be made in-situ, but must be confirmed in the laboratory if the objective is exceeded.

[6] The term chlorophenol means the sum of tri-, tetra-, and pentachlorophenol which may be present in water, sediment or fish.

[7] The maximum value should not be exceeded in bottom surface sediments taken in any part of the sub-basin, except in the initial dilution zones of effluents. The average of at least three replicate sediment samples taken from the same site should be used to check the objective.

[8] The objective applies only to fish muscle tissue, not the whole fish or organs, of a fish of any species caught in any part of the sub-basin, including the initial dilution zones of effluents.

[9] The term PCB's applies to the sum of Aroclor 1242, 1254, and 1260, which may be present in water, sediment or fish.

Source: Swain and Holms 1985.

TABLE 2
DRAFT PROVISIONAL WATER QUALITY OBJECTIVES FOR THE LITTLE CAMPBELL RIVER, NICOMEKL RIVER, SERPENTINE RIVER, AND THEIR TRIBUTARIES, AND BOUNDARY BAY
(PREPARED BY B.C. MINISTRY OF ENVIRONMENT AND PARKS)

Water Bodies	Little Campbell River	Mahood, Hyland and Latimer Creeks	Serpentine River	Nicomekl River	Anderson and Murray Creeks	Boundary Bay
Designated Water Uses / Characteristics	Aquatic life, wildlife, irrigation, livestock watering, primary contact recreation	Aquatic life, wildlife, irrigation, livestock watering	Aquatic life, wildlife, irrigation, livestock watering	Aquatic life, wildlife, irrigation, livestock watering	Aquatic life, wildlife, irrigation, livestock watering	Aquatic life, wildlife, primary-contact recreation
Fecal Coliforms[1]	≤200 MPN/100 mL geometric mean (April)	≤1000 MPN/100 mL geometric mean (April-October) ≤4000 MPN/100 mL maximum (April-October)				
	≤100 MPN/100 mL 90th percentile (year round) (long-term objective) ≤200 MPN/100 mL geometric mean (April-October) (long-term objective) ≤400 MPN/100 mL 90th percentile (April-October)(long-term objective)					≤14 MPN/100 mL median (year-round) (long-term objective) ≤43 MPN/100 mL 90th percentile (year round) (long-term objective)
Suspended Solids[2]	10 mg/L maximum increase (upstream ≤100 mg/L) 10% maximum increase (upstream >100 mg/L)					
Substrate Sedimentation[2]	No significant increase (95% confidence level) by weight in particulate matter for particulate <3 mm in diameter					
Turbidity[2]	5 NTU maximum increase (upstream ≤50 NTU) 10% maximum increase (upstream >50 NTU)					
Total Ammonia-N	See Tables 3 and 4					not applicable
Nitrite-N	See Table 5					not applicable
Chlorophyll-*a*[3]	50 mg/m² maximum	100 mg/m² max.:long-term objective		100 mg/m² maximum		not applicable
Dissolved Oxygen	6.0 mg/L minimum (June-October)	8.0 mg/L minimum	6.0 mg/L minimum (June-October)		8.0 mg/L minimum	6.5 mg/L minimum 9.0 mg/L minimum (long-term objective)
	11.0 mg/L (when fish salmonid eggs and alevin are present)					
	8.0 mg/L long-term objective for minimum (June-October)	not applicable	8.0 mg/L minimum (June-October) (long-term objective)		not applicable	

TABLE 2 (Continued)

Water Bodies	Little Campbell River	Mahood, Hyland and Latimer Creeks	Serpentine River	Nicomekl River	Anderson and Murray Creeks	Boundary Bay
Designated Water Uses / Characteristics	Aquatic life, wildlife, irrigation, livestock watering, primary contact recreation	Aquatic life, wildlife, irrigation, livestock watering	Aquatic life, wildlife, irrigation, livestock watering	Aquatic life, wildlife, irrigation, livestock watering	Aquatic life, wildlife, irrigation, livestock watering	Aquatic life, wildlife, primary-contact recreation
pH [5],[8]	6.5 - 8.5	6.5 - 9.0	6.5 - 8.5			not applicable
Total Lead	not applicable			0.005 mg/L maximum if hardness ≤95 mg/L 0.010 mg/L maximum if hardness >95 mg/L	not applicable	
Chlorophenols[4],[9]	not applicable	0.2 µg/L maximum in water 0.01 µg/g (dry-weight) in bottom surface sediments 0.1 µg/g (wet-weight) in whole fish		not applicable		
PCB's[7],[8],[9]	not applicable	0.001 µg/L maximum in water 0.3 µg/g (dry-weight) maximum in bottom surface sediments 0.1 µg/g (wet-weight) in whole fish		not applicable		

TABLE 2 (Continued)

Note: The objectives apply to discrete samples from all parts of the waterbodies, except from initial dilution zones of effluents. These excluded initial dilution zones are defined as extending up to 100 m downstream from a discharge, and occupying no more than 50% of the stream width around the discharge point, from the bed of the stream to the surface. These excluded initial dilution zones in the Bay are defined as extending up to 100 m horizontally in all directions, but not to exceed 25% of the width of the waterbody. The words "not applicable" indicate that a particular characteristic will likely not be affected by man's activities in that waterbody or a reach of the waterbody.

[1] The geometric mean, median and the 90th percentile are calculated from at least five samples taken weekly in a period of 30 days. The recreation objective (200-400/100 mL) applies during the recreation season and the drinking water objectives (10-100/mL) apply year-round.

[2] The increase (in mg/L, NTU or %) is over levels measured at a site upstream from a discharge or series of discharges and as close to them as possible, and applies to downstream levels.

[3] The average is calculated from at least five randomly located samples taken from natural substrates at each site on any one sampling date.

[4] Measurements can be made in-situ, but must be confirmed in the laboratory if the objective is exceeded.

[5] If upstream values in the Little Campbell or Serpentine Rivers are outside this range, there should be no change downstream from an outfall or series of outfalls.

[6] The objectives do not apply to Mahood or Latimer Creeks. The term chlorophenols means the sum of tri-, tetra-, and pentachlorophenol which may be present in the water, sediment, or biota

[7] The objectives do not apply to Hyland or Latimer Creeks.

[8] The term PCB's applies to the sum of Aroclor 1242, 1254, and 1260 which may be present in the water, sediment, or fish.

[9] The maximum value should not be exceeded in bottom surface sediments taken in any part of the sub-basin, except in the initial dilution zones of effluents. The average of at least three replicate samples taken from the same site should be used to check the objective.

Source: Holms and Swain (in prep.)

TABLE 3

MAXIMUM CONCENTRATION OF TOTAL AMMONIA-NITROGEN FOR PROTECTION OF AQUATIC LIFE
(mg/L-N)
(PREPARED AND ISSUED BY B.C. MINISTRY OF ENVIRONMENT AND PARKS)

pH	Temp. °C 0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
6.5	27.7	28.3	27.9	27.5	27.2	26.8	26.5	26.2	26.0	25.7	25.5
6.6	27.9	27.5	27.2	26.8	26.4	26.1	25.8	25.5	25.2	25.0	24.7
6.7	26.9	26.5	26.2	25.9	25.5	25.2	24.9	24.6	24.4	24.1	23.9
6.8	25.8	25.5	25.1	24.8	24.5	24.2	23.9	23.6	23.4	23.1	22.9
6.9	24.6	24.2	23.9	23.6	23.3	23.0	22.7	22.5	22.2	22.0	21.8
7.0	23.2	22.8	22.5	22.2	21.9	21.6	21.4	21.1	20.9	20.7	20.5
7.1	21.6	21.3	20.9	20.7	20.4	20.2	19.9	19.7	19.5	19.3	19.1
7.2	19.9	19.6	19.3	19.0	18.8	18.6	18.3	18.1	17.9	17.8	17.6
7.3	18.1	17.8	17.5	17.3	17.1	16.9	16.7	16.5	16.3	16.2	16.0
7.4	16.2	16.0	15.7	15.5	15.3	15.2	15.0	14.8	14.7	14.5	14.4
7.5	14.4	14.1	14.0	13.8	13.6	13.4	13.3	13.1	13.0	12.9	12.7
7.6	12.6	12.4	12.2	12.0	11.9	11.7	11.6	11.5	11.4	11.3	11.2
7.7	10.8	10.7	10.5	10.4	10.3	10.1	10.0	9.92	9.83	9.73	9.65
7.8	9.26	9.12	8.98	8.88	8.77	8.67	8.57	8.48	8.40	8.32	8.25
7.9	7.82	7.71	7.60	7.51	7.42	7.33	7.25	7.17	7.10	7.04	6.98
8.0	6.55	6.46	6.37	6.29	6.22	6.14	6.08	6.02	5.96	5.91	5.86
8.1	5.21	5.14	5.07	5.01	4.95	4.90	4.84	4.80	4.75	4.71	4.67
8.2	4.15	4.09	4.04	3.99	3.95	3.90	3.86	3.83	3.80	3.76	3.74
8.3	3.31	3.27	3.22	3.19	3.15	3.12	3.09	3.06	3.03	3.01	2.99
8.4	2.64	2.61	2.57	2.54	2.52	2.49	2.47	2.45	2.43	2.41	2.40
8.5	2.11	2.08	2.06	2.03	2.01	1.99	1.98	1.96	1.95	1.94	1.93
8.6	1.69	1.67	1.65	1.63	1.61	1.60	1.59	1.58	1.57	1.56	1.55
8.7	1.35	1.33	1.32	1.31	1.30	1.29	1.28	1.27	1.26	1.26	1.25
8.8	1.08	1.07	1.06	1.05	1.04	1.04	1.03	1.03	1.02	1.02	1.02
8.9	0.871	0.863	0.856	0.849	0.844	0.839	0.836	0.833	0.832	0.831	0.831
9.0	0.703	0.697	0.692	0.688	0.685	0.682	0.681	0.681	0.680	0.681	0.682

pH	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0
6.5	25.2	25.0	24.8	24.6	24.5	24.3	24.2	24.0	23.9	23.8
6.6	24.5	24.3	24.1	23.9	23.8	24.6	23.5	23.3	23.3	23.2
6.7	23.7	23.5	23.3	23.1	23.0	22.8	22.7	22.6	22.5	22.4
6.8	22.7	22.5	22.3	22.2	22.0	21.9	21.8	21.7	21.6	21.5
6.9	21.6	21.4	21.3	21.1	21.0	20.8	20.7	20.6	20.5	20.4
7.0	20.3	20.2	20.0	19.9	19.7	19.6	19.5	19.4	19.3	19.2
7.1	18.9	18.8	18.7	18.5	18.4	18.3	18.2	18.1	18.0	17.9
7.2	17.4	17.3	17.2	17.1	16.9	16.8	16.8	16.7	16.6	16.5
7.3	15.9	15.7	15.6	15.5	15.4	15.3	15.2	15.2	15.1	15.1
7.4	14.2	14.1	14.0	13.9	13.9	13.8	13.7	13.6	13.6	13.5
7.5	12.6	12.5	12.4	12.4	12.3	12.2	12.2	12.1	12.1	12.0
7.6	11.1	11.0	10.9	10.8	10.8	10.7	10.7	10.6	10.6	10.5
7.7	9.57	9.50	9.43	9.37	9.31	9.26	9.22	9.81	9.15	9.12
7.8	8.18	8.12	8.07	8.02	7.97	7.93	7.90	7.87	7.84	7.82
7.9	6.92	6.88	6.83	6.79	6.75	6.72	6.69	6.67	6.65	6.64
8.0	5.81	5.78	5.74	5.71	5.68	5.66	5.64	5.62	5.61	5.60
8.1	4.64	4.61	4.59	4.56	4.54	4.53	4.51	4.50	4.49	4.49
8.2	3.71	3.69	3.67	3.65	3.64	3.63	3.62	3.61	3.61	3.61
8.3	2.97	2.96	2.94	2.93	2.92	2.92	2.91	2.91	2.91	2.91
8.4	2.38	2.37	2.36	2.36	2.35	2.35	2.35	2.35	2.35	2.36
8.5	1.92	1.91	1.91	1.90	1.90	1.90	1.90	1.90	1.91	1.92
8.6	1.55	1.54	1.54	1.54	1.54	1.54	1.55	1.55	1.56	1.57
8.7	1.25	1.25	1.25	1.25	1.25	1.26	1.26	1.27	1.28	1.29
8.8	1.02	1.11	1.02	1.02	1.03	1.03	1.04	1.05	1.06	1.07
8.9	0.832	0.834	0.838	0.842	0.847	0.853	0.861	0.870	0.880	0.891
9.0	0.684	0.688	0.692	0.698	0.704	0.711	0.720	0.729	0.740	0.752

Source: Nordin and Pommen 1986

TABLE 4
AVERAGE 30-DAY CONCENTRATION OF TOTAL AMMONIA-NITROGEN FOR PROTECTION OF AQUATIC LIFE (mg/L-N)
(PREPARED AND ISSUED BY B.C. MINISTRY OF ENVIRONMENT AND PARKS)

pH	Temp. °C 0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
6.5	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
6.6	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
6.7	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
6.8	2.08	2.05	2.02	1.99	1.96	1.94	1.92	1.90	1.88	1.86	1.84
6.9	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
7.0	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
7.1	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
7.2	2.08	2.05	2.02	1.99	1.96	1.95	1.92	1.90	1.88	1.86	1.85
7.3	2.08	2.05	2.02	1.99	1.97	1.95	1.92	1.90	1.88	1.86	1.85
7.4	2.08	2.05	2.02	2.00	1.97	1.95	1.92	1.90	1.88	1.87	1.85
7.5	2.08	2.05	2.02	2.00	1.97	1.95	1.93	1.91	1.88	1.87	1.85
7.6	2.09	2.05	2.03	2.00	1.97	1.95	1.93	1.91	1.89	1.87	1.85
7.7	2.09	2.05	2.03	2.00	1.98	1.95	1.93	1.91	1.89	1.87	1.86
7.8	1.78	1.75	1.73	1.71	1.69	1.67	1.65	1.63	1.62	1.60	1.59
7.9	1.50	1.48	1.46	1.44	1.43	1.41	1.39	1.38	1.36	1.35	1.34
8.0	1.26	1.24	1.23	1.21	1.20	1.18	1.17	1.16	1.15	1.14	1.13
8.1	1.00	0.989	0.976	0.963	0.952	0.942	0.932	0.922	0.914	0.906	0.899
8.2	0.799	0.788	0.777	0.768	0.759	0.751	0.743	0.736	0.730	0.724	0.718
8.3	0.636	0.628	0.620	0.613	0.606	0.599	0.594	0.588	0.583	0.579	0.575
8.4	0.508	0.501	0.495	0.489	0.484	0.479	0.475	0.471	0.467	0.464	0.461
8.5	0.405	0.400	0.396	0.381	0.387	0.384	0.380	0.377	0.375	0.372	0.370
8.6	0.324	0.320	0.317	0.313	0.310	0.308	0.305	0.303	0.301	0.300	0.298
8.7	0.260	0.257	0.254	0.251	0.249	0.247	0.246	0.244	0.243	0.242	0.241
8.8	0.208	0.206	0.204	0.202	0.201	0.200	0.198	0.197	0.197	0.196	0.196
8.9	0.168	0.166	0.165	0.163	0.162	0.161	0.161	0.160	0.160	0.160	0.160
9.0	0.135	0.134	0.133	0.132	0.132	0.131	0.131	0.131	0.131	0.131	0.131

pH	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0
6.5	1.82	1.81	1.80	1.78	1.77	1.64	1.52	1.41	1.31	1.22
6.6	1.82	1.81	1.80	1.78	1.77	1.64	1.52	1.41	1.31	1.22
6.7	1.83	1.81	1.80	1.78	1.77	1.64	1.52	1.41	1.31	1.22
6.8	1.83	1.81	1.80	1.78	1.77	1.64	1.52	1.42	1.32	1.22
6.9	1.82	1.81	1.80	1.78	1.77	1.64	1.53	1.42	1.32	1.22
7.0	1.83	1.81	1.80	1.79	1.77	1.64	1.53	1.42	1.32	1.22
7.1	1.83	1.81	1.80	1.79	1.77	1.65	1.53	1.42	1.32	1.23
7.2	1.83	1.81	1.80	1.79	1.78	1.65	1.53	1.42	1.32	1.23
7.3	1.83	1.82	1.80	1.79	1.78	1.65	1.53	1.42	1.32	1.23
7.4	1.83	1.82	1.80	1.79	1.78	1.65	1.53	1.42	1.32	1.23
7.5	1.83	1.82	1.81	1.80	1.78	1.66	1.54	1.43	1.33	1.23
7.6	1.84	1.82	1.81	1.80	1.79	1.66	1.54	1.43	1.33	1.24
7.7	1.84	1.83	1.81	1.80	1.79	1.66	1.54	1.44	1.34	1.24
7.8	1.57	1.56	1.55	1.54	1.53	1.42	1.32	1.23	1.14	1.07
7.9	1.33	1.32	1.31	1.31	1.30	1.21	1.12	1.04	0.970	0.904
8.0	1.12	1.11	1.10	1.10	1.09	1.02	0.944	0.878	0.818	0.762
8.1	0.893	0.887	0.882	0.878	0.874	0.812	0.756	0.704	0.655	0.611
8.2	0.714	0.709	0.706	0.703	0.700	0.651	0.606	0.565	0.527	0.491
8.3	0.571	0.568	0.566	0.564	0.562	0.523	0.487	0.455	0.424	0.396
8.4	0.458	0.456	0.455	0.453	0.452	0.421	0.393	0.367	0.343	0.321
8.5	0.369	0.367	0.366	0.366	0.365	0.341	0.318	0.298	0.278	0.261
8.6	0.297	0.297	0.296	0.296	0.296	0.277	0.259	0.242	0.227	0.213
8.7	0.241	0.240	0.240	0.241	0.241	0.226	0.212	0.198	0.186	0.175
8.8	0.196	0.196	0.196	0.197	0.198	0.185	0.174	0.164	0.154	0.145
8.9	0.160	0.161	0.161	0.162	0.163	0.153	0.144	0.136	0.128	0.121
9.0	0.132	0.132	0.133	0.134	0.135	0.128	0.121	0.114	0.108	0.102

- the average of the measured values must be less than the average of the corresponding individual values in Table 4.
- each measured value is compared to the corresponding individual values in Table 4. No more than one in five of the measured values can be greater than one-and-a-half times the corresponding criteria values in Table 4.

Source: Nordin and Pommen 1986.

TABLE 5

MAXIMUM AND 30-d AVERAGE ALLOWABLE NITRITE (N) CONCENTRATIONS

(PREPARED AND ISSUED BY B. C. MINISTRY OF ENVIRONMENT AND PARKS)

Chloride Concentration (mg/L)	Maximum Nitrite-N Concentration (mg/L)	30-d Average Nitrite-N Concentration (mg/L)
<2	0.06	0.02
2-4	0.12	0.04
4-6	0.18	0.06
6-8	0.24	0.08
8-10	0.30	0.10
>10	0.60	0.20

Source: Nordin and Pommen 1986

TABLE 6
DRAFT PROVISIONAL WATER QUALITY OBEJCTIVES FOR TRIBUTARIES ENTERING THE FRASER RIVER MAIN STEM ALONG THE NORTH SHORE
(PREPARED BY B.C. MINISTRY OF ENVIRONMENT AND PARKS)

WATER BODIES	Kanaka Creek	Pitt Lake	Alouette Lake	Pitt River	Alouette River	N. Alouette River	Coquitlam River	Scott Creek	Or Creek	Brunette River	Still Creek	Burnaby Lake
DESIGNATED WATER USES / CHARACTERISTICS	Aquatic life, wildlife, drinking water (complete treatment plus disinfection), recreation, livestock, irrigation	Aquatic life, wildlife; drinking water (disinfection only); recreation; livestock, irrigation		drinking water (complete treatment plus disinfection); not applicable			Aquatic life, wildlife recreation, livestock, irrigation			Aquatic life, wildlife		
Fecal Coliforms[1],[2]	≤200/100 mL short-term geometric mean ≤400/100 mL short-term 90th percentile ≤100/100 mL long-term 90th percentile	≤10/100 mL 90th percentile		≤100/100 mL long-term 90th percentile		≤100/100 mL 90th percentile	≤200/100 mL geometric mean ≤400/100 mL 90th percentile		≤10/100mL 90th percentile	≤200/100 mL long-term geometric mean ≤400/100 mL long-term 90th percentile		
Suspended Solids[3]	not applicable	10 mg/L maximum increase (upstream ≤ 100 mg/L) 10% maximum increase (upstream > 100 mg/L)										
Substrate Sedimentation[3]	not applicable						No signficiant increase (95% confidence level) by weight in particulate matter <3mm in diameter				not applicable	
Turbidity[3]	not applicable	5 NTU maximum increase (upstream ≤ 50 NTU) 10% maximum increase (upstream > 50 NTU)										
Total Ammonia-N	See Tables 3 and 4											
Nitrite-N[1]	≤0.02 mg/L average 0.06 mg/L maximum										See Table 4	≤0.02mg/L average 0.06 mg/L maximum
Chlorophyll-a Periphyton[4]	≤50 mg/m² average	not applicable		≤100 mg/m² average			≤50 mg/m² average			≤100 mg/m² average		not applicable

TABLE 6 (Continued)

WATER BODIES	Kanaka Creek	Pitt Lake	Alouette Lake	Pitt River	Alouette River	N. Alouette River	Coquitlam River	Scott Creek	Or Creek	Brunette River	Still Creek	Burnaby Lake
DESIGNATED WATER USES / CHARACTERISTICS	Aquatic life, wildlife, drinking water (complete treatment plus disinfection), recreation, livestock, irrigation	Aquatic life, wildlife; drinking water (disinfection only); recreation; livestock, irrigation		Aquatic life, wildlife; drinking water (complete treatment plus disinfection); not applicable			Aquatic life, wildlife recreation, livestock, irrigation			Aquatic life, wildlife		
Dissolved Oxygen[2]	6.0 mg/L short-term minimum 7.75 mg/L long-term minimum 8.0 mg/L long-term minimum when fish eggs and/or larvae or alevin present 11.2 mg/L long-term minimum when eggs are in "eye" to "hatch" stage	5.0 mg/L minimum in hyplimnion 5 m above the sediment/water interface		7.75 mg/L minimum 8.0 mg/L minimum when fish eggs and/or larvae or alevin are present 11.2 mg/L when eggs are in the "eye" to "hatch" stage						6.0 mg/L short-term minimum 7.75 mg/L long-term minimum	4.0 mg/L short-term minimum 5.5 long-term minimum	5.25 mg/L short-term minimum 7.25 mg/L long-term minimum
pH[5]	6.5 - 8.5						not applicable			6.5 - 8.5		
Total Lead[3]	not applicable									20% maximum increase (upstream ≤0.005 mg/L) 0.001 mg/L maximum increase (upstream >0.005 mg/L)		

TABLE 6 (Continued)

<table>
<tr><th>WATER BODIES</th><th>Kanaka Creek</th><th>Pitt Lake</th><th>Alouette Lake</th><th>Pitt River</th><th>Alouette River</th><th>N. Alouette River</th><th>Coquitlam River</th><th>Scott Creek</th><th>Or Creek</th><th>Brunette River</th><th>Still Creek</th><th>Burnaby Lake</th></tr>
<tr><td>DESIGNATED WATER USES / CHARACTERISTICS</td><td rowspan="4">Aquatic life, wildlife, drinking water (complete treatment plus disinfection), recreation, livestock, irrigation</td><td colspan="5">Aquatic life, wildlife</td><td colspan="3" rowspan="4">Aquatic life, wildlife recreation, livestock, irrigation</td><td colspan="3" rowspan="4">Aquatic life, wildlife</td></tr>
<tr><td colspan="3">drinking water (disinfection only)</td><td colspan="3">drinking water (complete treatment plus disinfection</td></tr>
<tr><td colspan="3">recreation</td><td colspan="3">not applicable</td></tr>
<tr><td colspan="6">livestock, irrigation</td></tr>
<tr><td>Chlorophenols[6],[7],[8]</td><td colspan="3">not applicable</td><td>0.2 µg/L maximum in water 0.1 µg/g (wet weight) maximum in fish muscle 10 µg/g (dry weight) maximum in bottom surface sediments</td><td colspan="7">not applicable</td></tr>
</table>

Note:

The objectives apply to discrete samples from all parts of the water bodies, except from initial dilution zones of effluents. These excluded initial dilution zones are defined as extending up to 100 m downstream from a discharge, and occupying no more than 50% of the stream width around the discharge point, form the bed of the stream to the surface. In the Pitt River, the initial dilution zone will occupy no more than 25% of th stream width, and can extend up to 100 m upstream from a discharge at times of tide reversal. These excluded initial dilution zones in lakes are defined as extending up to 100 m horizontally in all directions, but not to exceed 25% of the width of the water body. This exclusion does not apply to objectives for fish as noted below.

[1] the average, geometric mean, and the 90th percentile are calculated from at least five weekly samples taken in a period of 30 days. For values recorded as less than the detection limit, the detection limit itself should be used in calculating the statistic.

[2] Long-term objectives indicate situations where existing water quality does not suit all desired water uses, but it is considered feasible to improve the water quality over time. Short-term objectives protect water uses to a certain degree until the long-term objectives can be achieved.

[3] The increase (in mg/L, NTU, or%) is over levels measured at a site upstream from a discharge or series of discharges and as close to them as possible, and applies to downstream levels.

TABLE 6 (Continued)

[4] The average is calculated from at least five randomly located samples from natural substrates at each site on any one sampling date.

[5] Measurements can be made in-situ, but must be confirmed in the laboratory if the objective is not achieved.

[6] The term chlorophenol means the sum of tri-, tetra-, and pentachlorophenol which may be present in water, sediment or fish.

[7] The maximum value should not be exceeded in bottom surface sediments taken in any part of the sub-basin, except in the initial dilution zones of effluents. The average of at least three replicate sediment samples taken from the same site should be used to check the objective.

[8] The objective applies only to fish muscle tissue, not the whole fish or organs, of a fish of any species caught in any part of the sub-basin including the initial dilution zones of effluents.

Source: Swain (in prep.)

TABLE 7
NAMES AND ADDRESSES OF SPEAKERS

Report Section in Appendix	Speaker
2.1	J. Armstrong U.S. Environmental Protection Agency Region 10 - Office of Puget Sound Seattle, Washington U.S.A. 98101
2.2, 2.3	L. G. Swain Water Management Branch B.C. Ministry of Environment and Parks 765 Broughton Street Victoria, B. C. V8V 1X5
2.4	D. Valiela Inland Waters/Lands Environment Canada Pacific and Yukon Region 502 - 1001 West Pender Street Vancouver, B. C. V6E 2M9
2.5	P. Khare Waste Management Branch Ministry of Environment and Parks Lower Mainland Region 15326 - 103 A Avenue Surrey, B. C. V3R 7A2
2.6	Gary L. Williams, Consultant to: North Fraser Harbour Commission 2020 Airport Road Richmond, B. C. V7B 1C6
2.7	B. D. Chang Fraser River, Northern B.C. and Yukon Division Department of Fisheries and Oceans 330 - 80 Sixth Street New Westminster, B. C. V3L 5B3

TABLE 7 (Continued)

Report Section in Appendix	Speaker
2.8	P. M. Chapman E.V.S. Consultants 195 Pemberton Avenue North Vancouver, B. C. V7P 2R4 R. Deverell A.S.L. Analytical Services Laboratories 1650 Pandora Street Vancouver, B. C. V5L 1L6 R. Jones, G. Marsh Greater Vancouver Regional District 4330 Kingsway Burnaby, B. C. V5H 4G8
2.9	L. Harding Environmental Protection Environment Canada Pacific and Yukon Region Kapilano 100, Park Royal West Vancouver, B. C. V7T 1A2
2.10	L. M. Churchland, G. Kan, F.T.S. Mah, T. Tuominen C. Baldazzi, S. Villeneuve Inland Waters/Lands Environment Canada Pacific and Yukon Region 502 - 1001 West Pender Street Vancouver, B. C. V6E 2M9
2.11	D. Goyette, M. Thomas Environmental Protection Environment Canada Pacific and Yukon Region Kapilano 100 - Park Royal West Vancouver, B. C. V7T 1A2

TABLE 7 (Continued)

Report Section in Appendix	Speaker
2.12	L. Copeland Boundary Health Unit B.C. Ministry of Health 14265 - 56 Avenue Surrey, B. C. V3W 1J1
2.13	W.F.A. Duncan Aquatrol Technologies Ltd. 200 - 260 W. Esplanade North Vancouver, B. C. V7M 3G7 G. Gough, B. Moore Waste Management Branch Ministry of Environment and Parks Lower Mainland Region 15326 - 103A Avenue Surrey, B. C. V3R 7A2
2.14	M. Waldichuk West Vancouver Laboratory Biological Sciences Department of Fisheries and Oceans 4160 Marine Drive West Vancouver, B. C. V7V 1N6
2.15	J. Carey, P.A. Coletta National Water Research Institute Environment Canada P.O. Box 5050 Burlington, Ontario L7R 4A6
2.16	K.J. Hall Westwater Research Centre University of British Columbia 1933 West Mall Annex Vancouver, B. C. V6T 1W5

TABLE 7 (Continued)

Report Section in Appendix	Speaker
2.16 (Con't)	C. Jacob Fraser River Harbour Commission 505 - 713 Columbia Street New Westminster, B. C. V3M 1B2
2.17	D.M. Wilson Environmental Protection Environment Canada Pacific and Yukon Region Kapilano 100 - Park Royal West Vancouver, B. C. V7T 1A2
2.18	I. H. Rogers West Vancouver Laboratory Biological Sciences Department of Fisheries and Oceans 4160 Marine Drive West Vancouver, B. C. V7V 1N6
2.19	I.K. Birtwell, G.M. Kruzynski, I.H. Rogers West Vancouver Laboratory Biological Sciences Department of Fisheries and Oceans 4160 Marine Drive West Vancouver, B. C. V7V 1N6 M.D. Nassichuk Habitat Management Division Department of Fisheries and Oceans Ste. 400 - 555 West Hastings Vancouver, B. C. V6B 5G3
2.20	D. Walton Waste Management Ministry of Environment and Parks Lower Mainland Region 15326 - 103 A Avenue Surrey, B. C. V3R 7A2

TABLE 7 (Continued)

Report Section in Appendix	Speaker
2.21	J.A. Stronach Pacific Ocean Sciences Ltd. 301A - 3700 Gilmore Way Burnaby, B. C. V5G 4M1 P.B. Crean, T.S. Murty Institute of Ocean Science Department of Fisheries and Oceans P.O. Box 6000 West Saanich, B. C. V8L 4B2
2.22	A. Ages Institute of Ocean Science Department of Fisheries and Oceans P.O. Box 6000 West Saanich, B. C. V8L 4B2
2.23	H. Schreier Department of Soil Science University of British Columbia 2357 Main Mall Vancouver, B. C. V6T 2A2
2.24	J.L. Luternauer Geological Survey of Canada 8th Floor 100 West Pender Street Vancouver, B. C. V6B 1R8
2.25	D. D'Amours Department of Oceanography University of British Columbia 6270 University Boulevard Vancouver, B. C. V6T 1W5
2.26	C. Jacob Fraser River Harbour Commission 505 - 713 Columbia Street New Westminster, B. C. V3M 1B2

APPENDIX
DETAILED PRESENTATION OF WORKSHOP PROCEEDINGS

1.0 INTRODUCTION

The February 1987 FREMP workshop was held for the following reasons:

1. to provide a forum for exchange of information between scientists actively carrying out research in the estuary;
2. to serve as a means for project coordination;
3. to overview the status of the estuary.

The format of the workshop involved speakers making short technical presentations over one and one-half days. On the afternoon of the second day, three working groups were convened to review and priorize water quality issues in the estuary.

2.0 ABSTRACTS OF PRESENTATIONS, QUESTIONS AND ANSWERS

Most of the speakers dealt with work carried out in the lower Fraser River and Estuary (addresses for the speakers are given in Table 7). In addition because a Water Quality Plan was under development for Puget Sound, a speaker familiar with Puget Sound issues was invited as the keynote speaker.

2.1 ADDRESSING POLLUTION PROBLEMS IN PUGET SOUND

J. Armstrong*, U.S. Environmental Protection Agency (EPA)

Pollution issues in Puget Sound are receiving more attention today than ever before. A new Washington state agency, the Puget Sound Water Quality Authority, and a new Federal program, the Environmental Protection Agency's Puget Sound Estuary Program, have brought both funds and high visibility to Puget Sound environmental issues.

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* Keynote Speaker

This presentation laid out the water quality planning and monitoring activities underway concerning the Sound. The U.S. agencies participating in Puget Sound issues were identified and their various environmental goals, programs and studies outlined. Individual investigators, and reports available, were identified for the Puget Sound studies. Finally, the overall approach to public education and public involvement was discussed. With the numerous similarities between environmental issues and problems in the marine and estuarine waters of Washington State and British Columbia, it is hoped that this presentation will initiate a period of greater interaction between scientists, managers and administrators in the two countries.

Questions and Answers:

Q. What kind of budget does EPA have for Puget Sound?

A. The EPA budget is about $1.5 million per year for the five year plan. We're now three years into the plan, but often these things don't end after the five years. In addition, the Puget Sound Water Quality Authority has requested about $19 million to implement the plan.

Q. What is your estimated budget per year for the water quality monitoring program?

A. The proposal is $3 million per year for the first three to five years, which would cover monitoring everything from sediments to fish tissue to nutrients. This budget will probably be cut back, but I don't know by how much.

Q. There was a big NSA program awhile back- I think a five year program. Was there a program based on that?

A. Not much. Those reports did focus our attention on certain chemicals and on certain areas; they gave us some tools to use. People from the NOAA (National Oceanographic and Atmospheric Administration) project worked with us, but they didn't get into the regulatory issues. The project got public attention, but the NOAA Ocean Assessments Division office in Seattle has now shifted much of its attention to San Francisco Bay.

Q. Have you associated tumours in bottom fish with any particular chemicals?

A. That's work NOAA is doing. There are some classes of compounds that are more associated with those tumours than other compounds. I don't know what they are. Peter, do you know?

A. (P. Chapman): Yes, PAH's.

Q. Does the Puget Sound Water Quality Authority have a separate budget, or do they get their funding from the State?

A. They are funded as a separate State agency. The Authority determines what other State agencies must do to manage Puget Sound. The Authority has no money to give to these other agencies; it must go to the State legislature and say: "This is our plan. You, the legislature, must approve the funding for these agencies to carry it out". This point is where we are now. Some of the funding will be approved, but how much remains to be seen.

Q. Can you expand on the power of the Water Quality Authority?

A. The Authority can tell an agency to develop a plan, which the Authority will approve, and to initiate it. For example, they can tell the State Department of Social Health Services to develop a survey of bacteria on recreational beaches. They can tell the State Department of Ecology to put biomonitoring into their program by a given date. They can also ask a county to ensure that cattle are kept out of streams, and they can set a time frame (eg., one year) for compliance.

Q. What happens if the State agency says, "We can't afford it"?

A. The Authority can say, "You shift some of your money into this program". If there still isn't enough money, the Authority must get the balance from the State legislature. That's where we are now. The Authority is confident it will get most of the money it has requested - - much of it will come from the cigarette tax. We have been lobbying the Authority to set priorities on its programs, because we don't think they will get enough money to fund everything.

Q. Seattle has a very fine lab on the Ship Canal. What is their mandate?

A. The lab belongs to the Municipality of Metro Seattle, which operates the sewage treatment plants for Seattle. There are 5 sewage treatment plants for Seattle which discharge into Puget Sound. They haven't had to do much monitoring to date but will have to do more in the future. The lab has been doing specific studies related to water quality in King County, where Seattle is located. They're doing more freshwater than marine studies. They also contract out their services.

Q. When you issue a permit for a discharge, is it done on the sole merits of that discharge, or does it take into account contaminants from other discharges in the same location? Are cumulative effects considered?

A. Cumulative effects aren't considered now, but ultimately they will be. With better monitoring studies, we may find that there is a problem from the combination of two discharges which alone are no problem. Right now we don't have that kind of information. When requests are made for permits, we have to use our best professional judgement about possible interactions; there is as yet no quantitative information.

Q. When you add more biological components to your monitoring program, there are some criteria you will have to set to determine acceptability of discharges. Have these criteria been decided upon yet?

A. No.

Q. Who is cracking the whip down there in terms of making things move?

A. The Water Quality Authority: it is a seven member group appointed by the governor. It has a staff of about thirty and a first year budget of about $1 million. They're asking for $3.5 million and an increased staff for the second year, because they're getting into the implementation phase. The Authority wants to work closely with each agency to ensure that its plan won't fail.

Q. You mentioned that combined sewer outfalls are a big problem. Does that mean you're going to separate those sewers?

A. It's an expensive and difficult problem to do anything about, but ultimately we'll see some kind of treatment at those outfalls -- settling ponds, for example. The goal is to get rid of the combined sewers altogether, but it's going to be a long time coming.

Q. What do you think the transboundary pollutants are?

A. They include contaminants from poor sewage treatment in Victoria and from the highly industrialized areas on the Fraser River. There are currently some transport studies. I can't be more specific. We plan to start looking into the problem this year.

Q. How are your advisory committees constituted?

A. We have many different advisory committees. There is a citizens' advisory committee for each urban bay, in addition to representatives from industry. For each bay where toxics are a problem, there are both a citizens' committee and a technical committee. Industry is represented on both committees. The function of the citizens' committee is to keep the technical committee honest and to raise questions which the technical committee may have missed. The technical committee must respond to the citizens. The Authority has held meetings in perhaps twenty-five cities around the State to obtain public input. They are now debating whether to have a Puget Sound-wide citizens' committee.

Q. Was the decision to upgrade sewage treatment from primary to secondary in Puget Sound based on a site-specific assessment of each discharge, or was it an across-the-board decision that all sewage treatment plants should be upgraded?

A. Originally, the federal regulations under which we were operating stated that if a discharge to saltwater passed a series of tests and showed no environmental impact, the sewage treatment plant could obtain a waiver allowing it not to upgrade for 5 years. All plants discharging to freshwater had to upgrade to secondary treatment. Then the State legislature reviewed its law and decided that all sewage treatment plants must have the "best available treatment", which was interpreted to mean "secondary treatment". At that point, EPA stopped evaluating requests for waivers because we couldn't consider them since the State required secondary treatment. This has been a big controversy, since water quality had nothing to do with the decision to upgrade. Some waivers might have been justified.

Q. What work is being done to show that upgrading of sewage treatment is the best use of the funds or to find better alternatives?

A. Essentially none. Upgrading is state law. The state legislature has several times refused to vote on changes to that law.

Q. You mentioned your $3 million water quality monitoring program. How many sites will you be looking at, how many replicate samples, etc.? If there are going to be cutbacks, where could you cut it back, for example, to a $0.5 million program?

A. Originally we asked a consultant to give us high, medium, and low programs that would be acceptable. We were given a $3 million, a $5 million and an $8 million program. Then we decided that if a $3 million program was acceptable, we shouldn't consider the more expensive programs. The $3 million program includes about 105 stations. There will be at least one station in each bay, with

three to five stations in each big, urban bay where water quality changes can be expected. The components monitored will include the water column, fish diseases, sediment chemistry - the whole gamut. Riverine inputs will also be monitored. To cut back on the plan, we'll probably go to the rural bays less frequently, for example, every third year. The plan will be reduced in scope quite a bit, but the annual cost probably will not go below $1.5 - 2.0 million.

2.2 SETTING WATER QUALITY OBJECTIVES: THE FRASER RIVER ESTUARY

L.G. Swain, Water Management Branch, B.C. Ministry of Environment and Parks

The B.C. Ministry of Environment and Parks is preparing water quality assessments and Objectives in priority water basins in British Columbia. Provisional Objectives for the Fraser River Estuary were finalized in 1985.

This paper discusses the general approach to proposing provisional Water Quality Objectives. This includes the concept of designated water uses, highest and best use for each water quality constituent, "working" and established Water Quality Criteria, initial dilution zones and mixing zones, and different types of Water Quality Objectives.

The established Objectives and the rationale for their selection are then reviewed. This includes a general discussion on choosing water quality constituents for which Objectives are needed, and the rationale for the Fraser River Estuary Objectives.

Discussion is presented on how these may be modified in the future, prior to the provisional Water Quality Objectives being made permanent.

Questions and Answers:

Q. Can you comment on the absence of mercury from your Objectives?

A. We didn't see any significant sources of mercury in the assessment area. When we set Objectives for a contaminant, there must be a potential source of that particular contaminant over which we can have some control. Mercury is probably entering the lower Fraser

in significant quantities from the upper watershed - from the Pinchi Falls area through the Nechako system - but unless we can pinpoint sources of mercury that we can control, there would be no point in setting Objectives.

R. The issue here is that some problems with mercury levels have been detected with biomonitoring in the estuary, and that is why I asked whether an Objective had been considered.

A. Yes, we considered it.

Q. Could you comment on the difference in the Objective for dissolved oxygen between the Fraser River and Sturgeon and Roberts Banks? My concern is that in both locations there are both marine and freshwater [species] in a highly stratified estuary. I understand that the Criteria were designed to protect biological components. I wondered what the rationale was for the differences in those values between the 9.0, which I fully support, and the 7.75, about which I am skeptical.

A. The rationale has been that we were considering the river as basically a freshwater system. I've had discussions with Steve (Samis) since then, and he feels that the 9.0 should be applicable within the whole area. That's one of the advantages of provisional Objectives: we'll have time to review that in five years or so.

Q. I see that un-ionized ammonia is not applicable in the Main Stem. By "Main Stem", are you referring all the way to Prince George?

A. No, in this report Main Stem is defined as extending from Kanaka Creek to New Westminster.

Q. Why is un-ionized ammonia not considered applicable?

A. We didn't think that with the flows in the Main Stem, and with the minor amounts of sewage inputs, that there would be any problems.

2.3 FRASER RIVER ESTUARY MONITORING: A RECOMMENDED APPROACH: 1985 RIVERINE DATA

L.G. Swain, Water Management Branch, B.C. Ministry of Environment and Parks

In 1986, the Ministry of Environment and Parks contracted $100 000 per year for five years to the Fraser River Harbour Commission (FRHC) for

monitoring, as proposed in a program prepared by a federal-provincial committee and called: "Fraser River Estuary Monitoring - A Recommended Approach". The program involves monitoring discharges, water, sediment, and biota on a 5-year cycle. The Ministry undertook a survey in January and February 1985, as preliminary work under this agreement, to:

1. Determine if site locations proposed by the federal-provincial committee were appropriate for successful sample collection.

2. Determine to what degree values in sediments and fish would meet provisional Water Quality Objectives, recognizing that sufficient data were not collected to determine definitely the status of water quality or achievement of the Objectives.

Two of the eleven Objectives set for the lower Fraser River in 1985, relate to PCB's and chlorophenols in fish and sediments. Another paper presented to this workshop indicated that the other nine Objectives are usually achieved. Results from the 1985 preliminary study reveal that the Objectives for PCB's and chlorophenols in fish were achieved but that the Objectives for sediments, as had been recognized when they were set, were not achieved at three of six sites.

Further sampling to check possible sources of these contaminants was undertaken in 1986 by the Ministry through the FRHC. In future years, the FRHC will carry out further sampling at these sites to determine if the 1985 contaminant values, and the Objectives are realistic.

Questions and Answers:

Q. Would you clarify your statement that the priority on the Fraser has been to monitor effluents? Which effluents, in particular, were you looking at? You appear to be looking at points on the river, not effluents.

A. These samples were not supposed to look at effluents per se. The sites chosen were intended to reflect the general quality of the different arms rather than to show the effect of any particular

effluent. This year we went to different effluents to do site-specific studies. Those sites included the sewage treatment plants, two to three forest industry operations, three to four metal finishing plants, and a cement operation.

Q. Did you measure carbon content or identify sediment types in the different zones?

A. We measured carbon content and grain size composition. As you would expect, the structure changed from zone to zone. There were sands upstream grading to finer materials closer to the ocean. The report is available if you're interested in the data.

Q. Did you analyze the sediment as a whole, or did you analyze the fine fraction separately?

A. We analyzed it as a whole.

Q. Do you have any evidence that where the sediment Criteria were exceeded there were adverse biological effects?

A. No, the fish were fine in all the areas. I can't recall whether we saw anything in the benthic material.

Q. Are you going to reevaluate your Criteria if there were no biological effects?

A. The Objectives we have established are provisional and based on the working Water Quality Criteria. The Ministry is currently reviewing PCB's and chlorophenols to establish official Criteria. So, yes, eventually the Criteria will be reviewed, and biological effects will be taken into account.

2.4 INFORMATION TO SUPPORT DEVELOPMENT OF WATER QUALITY OBJECTIVES FOR THE FRASER ESTUARY

D. Valiela, Inland Waters/Lands, Environment Canada

Development of Water Quality Objectives for the Fraser Estuary requires integration of site-specific data on chemical, physical, and biological characteristics and their variability with toxicological cause-effect information. For a system as complex as the Fraser Estuary, these information demands are considerable. Existing data on chlorinated phenols are examined as an example of the information that exists versus the information that would be required to formulate scientifically defensible Water Quality Objectives.

Measurements of maximum reported concentrations of pentachlorophenol in water in the Fraser Estuary range from 0.056 to 2.25 µg/L; of maximum concentrations of tetrachlorophenol in water, from 0.13 to 11.0 µg/L. In biota, reported maximum concentrations range from 79 to 2768 ng/g for penta- and from 49 to 2522 ng/g for tetrachlorophenol. In fish tissues pentachlorophenol content tends to be higher than tetrachlorophenol content, while in water samples the reverse is true. Content of chlorophenols in tissues has been expressed on a wet weight basis by some authors, but should be reported as grams per gram dry weight of tissue. Very few data are available on chlorophenol concentrations in bottom sediments; these report maximum values that range from 19 to 56 ng/g dry weight of sediment. The variability in the available data may be due to real site-to-site and time of sampling differences, to differences in the age of fish analyzed, mobility and previous exposure of fish to chlorophenols, chemical analysis differences among labs, poor or nonexistent sampling replication, or a variety of other factors. More systematic and intensive sampling is required to characterize the concentrations of chlorophenols presently found in the Fraser Estuary. It is also possible that other indicators (invertebrates, sediments, bioassays, etc.) may be more suitable than the variables measured to date to describe the chlorophenol levels found.

Existing information on toxicology of chlorophenols is equally uncertain. Criteria for aquatic life found in the literature range from 1.84 ng/L to 0.05 ng/L in water. The B.C. MoEP provisional Objectives for the Fraser Estuary are 0.20 µg/L in water; 100 ng/g wet weight of tissue in fish and 10 ng/g dry weight of sediments as a yearly mean of 3 samples. It is clear that even at these Objective levels, which are provisional because they are based on a limited data set, exceedances are commonly found in the reported concentrations in all three types of media in the Fraser Estuary.

There is a clear need for better information on toxicity of chlorophenols to fish and humans, on existing levels and variability in the Fraser Estuary, and on the relative advantages and disadvantages for monitoring of different indicators of chlorophenol contamination.

No questions

2.5 WASTE MANAGEMENT ACTIVITY PROGRAM

P. Khare, Waste Management, B.C. Ministry of Environment and Parks

(No abstract.) P. Khare outlined the functions and goals of the FREMP Waste Management Activity Program.

No questions.

2.6 NORTH FRASER HARBOUR ENVIRONMENTAL MANAGEMENT PLAN

Gary L. Williams, Consultant for the North Fraser Harbour Commission

The North Fraser Harbour Environmental Management Plan, initiated by the North Fraser Harbour Commission (NFHC), is intended to be operational by the spring of 1987. The main objective of the Plan is to make environmental considerations an integral component of port planning by formulating a proactive (as opposed to reactive) and cooperative management system. The Plan has been developed cooperatively with senior regional habitat biologists with the Department of Fisheries and Oceans (DFO). The proposed Plan is currently being reviewed by DFO to ensure that the Plan is fully compatible with national fish management habitat policy.

The Plan consists of four main components: shoreline habitat classification, development site assessment procedures, habitat compensation and cooperative management program. In July 1986 a joint NFHC-DFO field

program and data review was undertaken, and shoreline classification and effluent discharge maps were produced to provide baseline data for developing the Plan.

Under the cooperative management program, water quality will be enhanced by establishing good "harbourkeeping" practices by harbour users, working with industries and municipalities to reduce discharges of contaminants into the harbour, enhancing communications between the NFHC, DFO and other agencies, and undertaking applied research projects.

Questions and Answers:

Q. Do you have any information on the water quality of the ditches that drain the East Richmond cranberry fields? Spraying could be a problem there.

A. I went out and talked to (cranberry farmers in this area) because that is a concern I had. I think they're spraying parathion, and there is significant runoff. There are no data available.

R. There is some monitoring, some bioassay work, going on with respect to the cranberry fields. There should be some information available.

A. I'm drawing up a report with recommendations for the Management Plan. I hope over the next few months to be going to various agencies that have a mandate in water quality and talking to people. I may get guidance from some of you.

Q. What regulations are there concerning dredging along the Fraser Harbour?

A. I can't answer that. Perhaps the Coast Guard could.

2.7 DFO CONCERNS WITH CURRENT WATER QUALITY MONITORING PROGRAMS AND OBJECTIVES IN THE FRASER RIVER ESTUARY

B.D. Chang, Department of Fisheries and Oceans

Within the Habitat Management Unit of the Fraser River, Northern B.C. and Yukon Division of DFO, the Water Quality Section consists of two full time staff. For this reason, water quality sampling is restricted to responses to pollution incidents. For data on background water quality conditions and long-term trends, we must depend on monitoring programs carried out by other agencies. DFO is concerned with the apparent lack of coordination among the water quality monitoring and enforcement programs of the various agencies. Committees such as those of FREMP and the GVRD Liquid Waste Management Plan should result in an improvement of this situation. Monitoring should emphasize effluents since by knowing what is entering into a system, potential problems can be identified much earlier than could be determined from water quality trends in the river itself. There is a need to estimate better inputs due to non-point sources such as agriculture run-off. Most monitoring has been done in the main river channels, while little work has been done in sloughs and side channels which are more important as fish habitat. These areas are also more susceptible to degradation due to lower dilution rates and because discharges often impinge directly onto such areas. It is important to emphasize that water quality is one component of fish habitat and that the overall value of a site as fish habitat must be considered when setting Water Quality Objectives.

Questions and Answers:

Q. What is Fisheries doing to protect some of this high value habitat?

A. To protect water quality we work with Environmental Protection and the provincial Waste Management Branch through the permit system. We also respond to instances of pollution and do some monitoring.

R. Have you ever thought of a conservation strategy to protect these areas both physically and from water pollution?

A. Yes, we have thought of it.

R. Then why aren't you proceeding in a concrete fashion? I think this is one of the basic issues. We know the important habitats, but we seem to do little about trying to protect them. We need to set some strategy, or we're going to see the habitat slowly erode.

A. Part of the idea of FREMP and the GVRD committees is to deal with this problem.

2.8 ENVIRONMENTAL MONITORING FOR THE IONA DEEP SEA OUTFALL

P.M. Chapman, E.V.S. Consultants, R. Deverall, A.S.L., and R. Jones and G. Marsh, Greater Vancouver Regional District

A pre-discharge environmental monitoring program was implemented in 1986 for the deep submarine outfall presently under construction at the Iona Island Sewage Treatment Plant. This monitoring program included: measurements of selected organic contaminants in monthly effluent composites (January-December); twice yearly (March and June) water quality monitoring for conventional parameters, bacterial indicators, nutrients, inorganic and organic contaminants; yearly sediment quality monitoring for conventional parameters, bacterial indicators, inorganic and organic contaminants (March); and, yearly biota monitoring for tissue contaminant concentrations and histopathological abnormalities (June-August).

The results of the effluent monitoring indicated that concentrations of organic contaminants in the effluent were highly variable on a monthly and a yearly basis. With the exception of fecal coliform analyses, water quality monitoring results showed a similar high level of variability both between the two sampling occasions and when compared to previous studies. Fecal coliform levels were consistently higher in surface waters near the present outfall.

In contrast, with the exception of bacterial indicators, sediment quality monitoring showed a low level of variability between stations and when compared to previous studies. The deep submarine outfall area appears to comprise a very well mixed depositional regime. Levels of all measured contaminants were similar to levels determined for various West Coast reference areas.

The results of the biota monitoring indicated that tissue contaminant concentrations in specific organisms and tissues were highly variable. Comparison with similar data from a previous study indicated a high degree of annual variability for the same species and tissues. However, levels of all measured contaminants were similar to levels determined in reference areas of Puget Sound, Washington State. Histopathological analyses determined high levels of various epidermal, gill and liver abnormalities in bottomfish, but the particular abnormalities detected are not considered to be related to anthropogenic pollution. Only a very low level of potentially idiopathic lesions related to pollution were detected.

Questions and Answers:

Q. What confidence level can you put on your water quality and sediment samples, based both on your sampling and on your analytical procedures?

A. John Park is here from A.S.L; he can talk about the chemistry. What do you mean by confidence level?

R. For example, were they single grab samples? How many replicates were there? What was the variability within samples?

A. We took six sediment samples. Two of these were analyzed; the rest were stored for future analyses, which would depend upon the variability we found. The variability was very low, but I'd have to look at the report to see exactly how different the samples were. The water samples were single samples. Of course, the water is highly variable. In two instances we were mandated to go out and take those measurements. I can question how much they mean as well as you can.

R. I think you must be very cautious about your conclusions 1) that there is no variability in the sediments and 2) that there are no effects of pollution out there.

A. I didn't say that there was no effect of pollution. I said that we couldn't draw that conclusion because we did no bioeffects monitoring. What I'm saying about the sediments is that over that enormous area, they are very uniform. Compared with previous work, the sediment doesn't change very much, and that's surprising.

R. I don't think you can say that from two samples.

A. Fine. Give us some money, and we'll analyze the rest of them.

Q. Did you do any split sample analysis or spike analysis of the organic contaminants?

A. Yes. A full QA-QC (Quality Assurance-Quality Control) was done with all tests blind. We used spikes, reference standards, split samples. It turned out very well.

2.9 TRACE METAL AND ORGANIC CONTAMINANTS IN SEDIMENTS AND BIOTA FROM ROBERTS AND STURGEON BANKS, 1984-1986

L. Harding, Environmental Protection, Environment Canada

Surveys of chemical contaminants in sediments and benthic fish and invertebrates were undertaken in the outer Fraser River Estuary during 1984-1986. Trace metals were found in very high levels in sediments near the Iona sewage treatment plant, and were only moderately elevated in other portions of the estuary. The levels of trace metals were strongly correlated with organic content, but not with particle size. Tissues of intertidal invertebrates reflected trace metal levels in sediments, with animals living near the Iona outfall generally having much higher levels than those elsewhere in the estuary. The pattern of decreasing trace metal levels with distance from the Iona outfall was essentially unchanged since a 1976 survey of the same sampling stations.

Tissues of epibenthic animals obtained by trawl showed elevated levels of arsenic, cadmium and mercury off Roberts Bank, and high levels of arsenic and lead off Iona. Canadian guidelines for contaminants in edible tissues were frequently exceeded for arsenic in fish, shrimp, prawns and dungeness crabs at Roberts Bank and Sturgeon Bank, and for lead in dungeness crabs and prawns at Sturgeon Bank.

Polychlorinated biphenyls and chlorinated phenols were below detection limits in sediments at all intertidal stations. Polycyclic aromatic hydrocarbons were detected at relatively low concentrations in intertidal and deep benthic sediments near the Iona outfall, but were below detection limits elsewhere on Sturgeon Bank and Roberts Bank.

Questions and Answers:

Q. The PAH's were quite similar between the station near the outfall and the one further out. It doesn't show much difference, does it?

A. Virtually no difference. I think the reason is that PAH's have strong affinities with sediment, are fairly mobile geographically, not all that mobile chemically, and very mobile biologically. Since the outfall goes out that way, it seems clear that it's the influence of the Iona outfall.

Q. Were the samples single surface grabs or was a composite made for each sample?

A. They were single surface grabs. There was a fairly extensive quality control procedure done by the lab, but I don't know the details of it.

Q. One wonders how much the variability, for example, of five samples at one station would compare with the variability between an inshore station and an offshore station.

A. The analytical variability is about a factor of two. The variability between two grabs at one station or between different stations is generally higher, but where the analytical variability is a factor of two, we can't be too precise.

Q. Can you arrange to have fish samples taken on the Banks?

A. We didn't collect any fish on the Banks, but we took a number of infaunal samples for polychaetes.

2.10 COMPARISON OF COLLECTION TECHNIQUES FOR THE MEASUREMENT OF CONTAMINANTS IN SUSPENDED SEDIMENTS FROM THE FRASER RIVER ESTUARY

L.M. Churchland, G. Kan, F.T.S. Mah, T. Tuominen, C. Baldazzi, S. Villeneuve, Inland Waters/Lands, Environment Canada

Previous studies have indicated that suspended sediments are the principal means of fluvial transport for metals and certain organic contaminants such as polychlorinated biphenyls. Two continuous flow centrifuges were compared for the collection of suspended sediments from the Lower Fraser River, where the transport and deposition of contaminants is of concern.

The Alpha/Laval and Westphalia centrifuges were tested on cruises to the Main Arm near New Westminster and Annacis Island in February and July of 1986. To determine whether submersible pumps provided a representative sample of river water to the centrifuges, total suspended sediment concentration and particle size were compared in pumped samples and samples collected with a USP63 sampler. To determine the efficiency of sediment recovery, total suspended sediment concentration and particle size were measured at the intake and outlet of each centrifuge.

At most river velocities, there was no difference in total suspended sediment concentration or percent sand, silt, and clay in samples collected with the USP63 sampler and the submersible pumps. This was the case despite the fact that the velocity at the pump intake was not adjusted to correspond to the variable river velocity.

At the pumping speed of 4 L/minute, there was either a) no difference in total suspended sediment concentration at the outlet of the Alpha/Laval

and Westphalia centrifuges or b) slightly higher concentrations in the outlet of the Westphalia centrifuge. The usual amount lost through the outlets was 0.5 to 10 mg/L which was approximately 1 to 10% of the total suspended sediment concentration. For both centrifuges, the majority of particles lost through the outlet was less than 1 µm in diameter. When the effluent from each centrifuge was examined using the Coulter Counter, there were greater numbers of particles for most size classes up to 5 µm in the Westphalia effluent. The exception was that, after longer operating times, the efficiency of the Alpha/Laval centrifuge was usually less than the Westphalia for particles larger than one micron.

When the sediments from within the centrifuge bowls were compared, there was no difference in percent sand, silt, and clay. There was no difference in the concentration of metals except for lower levels of lead and copper in sediments from the Westphalia centrifuge. Levels of polychlorinated biphenyls, polycyclic aromatic hydrocarbons, and chlorinated phenols will be compared when analytical results are received.

Questions and Answers:

Q. How would you adjust the intake speed?

A. There is a valve on top of the centrifuge bowl with which you can control the intake speed. Both centrifuges were operated at 4 L/min.

Q. First, I'd like to compliment you on a well-organized study. It's the type of work I like to see done on the Fraser River. My one concern is the turn-around time of some analyses. Some of those samples were taken in February, 1986, and you still don't have the chlorinated phenol data. If you want to use that technique for monitoring, it's going to be a slow process. Can you comment on that?

A. Our national lab in Burlington is doing the analyses. We loaded them down with samples this year. I hope we can improve the turn-around time in the future. Otherwise, I agree, there is a problem. We don't understand the effects of storing chlorophenol samples. Fred, do you want to comment on that?

R. (F. Mah) We will be starting a study of storage time this year.

Q. Was any thought given to putting water in the sediment bowls and determining background levels. Is there any contribution to your values from the centrifuge itself?

A. (J. Carey) It has been done. We also put in extracted saline, and ran Winnipeg tap water through. It picks up a lot.

Q. Would you expect any difference in the population of smaller particle sizes in brackish water?

A. I haven't thought about that. One concern is what happens when you have high concentration of phytoplankton cells, and they burst in the centrifuge releasing their contents. This is probably more likely in seawater or brackish water.

2.11 OVERVIEW OF BENTHIC ENVIRONMENTAL QUALITY STUDIES IN VANCOUVER HARBOUR

D. Goyette and M. Thomas, Environmental Protection,
Environment Canada

Since May 1985, Environmental Protection has been conducting benthic environmental quality studies in Vancouver Harbour. Six surveys covering the spring, fall and winter periods have been completed to determine the level of selected contaminants in surficial sediments and trawl caught species throughout the harbour. Sampling sites were located in the outer, inner, and central portions of Burrard Inlet, extending into Port Moody Arm. Sediment samples are being analyzed for total trace metals, polycyclic aromatic hydrocarbons (PAH's), total hydrocarbon, polychlorinated biphenyls (PCB's), chlorinated phenol, oil and grease content, along with particle size. Biological sampling focused on trace metal, concentrations of PAH's and PCB's in muscle and liver tissue from English sole (Parophrys vetulus) and muscle and hepatopancreas from the dungeness crab (Cancer magister). The relationship between sediment concentrations of PAH's and incidence of liver lesions in English sole is also being examined. Enumeration of trawl catches will provide information on utilization of Vancouver Harbour

(relative seasonal abundance and distribution) by various epibenthic species and the significance of contaminant uptake identified in selected species.

The benthic environment can serve as a depository for the variety of liquid and air borne contaminants originating from industrial and urban activity. The level and geographical distribution of contaminants in the benthic sediments is often a reflection of the long-term accumulative effects from point and non-point sources. This distribution can assist in identifying potential environmental problems, isolating and priorizing major sources of input for future control measures. Knowledge of contaminant levels and health of the biota living in direct contact with contaminated sediments provides one important measure of their biological impact and public health safety. Results will be used towards increasing the effectiveness of waste management practices for the harbour area.

Questions and Answers:

Q. Why didn't you look at infauna?

A. There is a considerable cost factor, and this study was the first cut. When we understand the distribution of contaminants in the epibenthic community, the next step would be sediment bioassays and infaunal studies.

Q. The epifauna are animals that move around; you can't pinpoint where they came from. This is particularly true of flatfish.

A. Flatfish populations appear to occupy definite areas. True, there is movement in and out, and it would be difficult to pinpoint what sources are actually causing contamination. Because there is harvesting, one of the thrusts of this study has been to determine the contaminant levels in the edible portions of species being harvested. After we have done that, we can be more refined and detailed.

Q. Are any of the Canadian action levels for concentrations in tissues exceeded in this instance?

A. It's a little early to say that, as we're still doing the analyses.

Q. You have to take for granted that there will be parasitic infections in fish, but with increasing stress caused by contaminants, you might expect an increased incidence of infection. Is there any correlation between parasitic infection, fin erosion or neoplasms and sediment chemistry?

A. We don't have all the information yet, but I doubt that we will see that. The external lesions and the degree of parasitism reflect more the general condition of the environment. We have seen a high incidence of blood spotting on the flatfish, which could be a bacterial infection. We haven't seen that in the other coastal areas we have monitored. The correlation that has the chance of being the most definitive is the one between neoplasms in flatfish and PAH's.

2.12 RECREATIONAL BEACH WATER QUALITY

L. Copeland, B.C. Ministry of Health, Boundary Health Unit

No abstract. (L. Copeland presented results of the Boundary Health Unit's monitoring for microbiological water quality in recreational beach water in the Lower Mainland).

Questions and Answers:

Q. You are assuming that the source of fecal contamination on Wreck Beach is the users of the beach. It needn't be so. There are some areas of the North Arm around Mitchell Island which have no sewers.

A. I wasn't assuming that. I don't think that the users of the beach are the major source of contamination.

R. We have been picking up levels of coliforms from the several hundreds to the low thousands at the Oak Street Bridge.

Q. Did you find any correlation between the periodic very high coliform levels and the stage of the tide?

A. Because of limited resources, we haven't sampled at many different periods. We try to take our samples as close to high tide as possible.

Q. It is important to sample at low tide if you are trying to evaluate runoff from farmland. This applies particularly to the area around Crescent Beach.

A. Could you clarify that comment?

R. On the high tide, the relatively cleaner seawater is backing up over the monitoring sites. On the ebbing tide, outflow from the Serpentine and Nicomekl Rivers, which drain farmland, will probably have much more significant effects.

A. It certainly would be worth investigating, but to sample Crescent Beach and White Rock on the low tide would be a full day's project. Part of our problem is resources.

2.13 DISSOLVED OXYGEN DEMAND IN THE SERPENTINE RIVER USING IN SITU CHAMBERS

W.F.A. Duncan, Aquatrol Technologies Ltd. and G.R. Gough and B. Moore, Waste Management, B.C. Ministry of Environment and Parks

A new commercially available production/respiration chamber (PRC ST 864; Aquatrol Technologies Ltd.) was tested in the Serpentine River System. Low dissolved oxygen (DO) levels in the lowland reaches during the autumn have resulted in fish kills. The low DO levels are related to agricultural discharges, water temperature, rainfall and river flow patterns (related to tidal influence). The chambers were used to assess the relative importance of the various causal factors.

Oxygen demand and production of the water column and the sediments were measured *in situ* in the Serpentine River and the Harvie Road Ditch (draining a dairy farm with approximately 150 cattle). The oxygen demand of corn silage and ditch water diluted 1:1 with river water were also measured *in situ* at the Serpentine River site. Sampling dates were scheduled to represent before, during and after periods of the first flush rain event in the autumn. Nutrients, specific conductivity, light, temperature, DO and chemical oxygen demand (COD) of the ditch and river were measured concurrently with the field testing of the chambers.

The first flush event caused the specific conductivity and ammonia levels in the ditch to decrease and to increase in the river. The

phosphorus level decreased with the flush in both the ditch and the river, while nitrate and nitrite levels increased; toxic levels of ammonia present in Harvie Road Ditch before the flush, were greatly reduced by the flush.

Water column dissolved oxygen demand was highest in the ditch chamber, ditch:river mix and corn silage:river mix chambers in the Serpentine River. Water column dissolved oxygen production was highest in the ditch and ditch:river mix chambers after the flush and in the Serpentine River. No oxygen production was observed in the corn silage:river mix chamber or in the ditch chambers before the flush event. Sediment oxygen demand was highest in the ditch sediments and lowest in the river. High sediment oxygen production was observed prior to the flush in the Serpentine River.

The low DO levels in autumn appear to be related to all the suggested factors. However, preliminary results suggest the oxygen demand of the agricultural runoff is the primary factor which can be compounded by the other factors.

Questions and Answers:

Q. The flow of water in your chamber probably affects the oxygen uptake. Have you tested that, and have you tested different starting levels of dissolved oxygen? I don't think that the oxygen consumption of the sediment would be linear with respect to the dissolved oxygen concentration.

A. You're right; it's not linear below 2 ppm oxygen. I had to aerate the chamber to make it work, because you can't demand oxygen from nothing.

Q. Some of the oxygen demand values you found are very similar to those found in the Thames Estuary in the highly polluted periods.

A. Yes, they're fairly high. I did some work on low nutrient coastal streams in southeast Alaska, and these values are an order of magnitude higher.

Q. Do you think there would be a higher oxygen consumption at night?

A. Oxygen consumption is dependent upon temperature. If the temperature dropped at night, it would probably go down. I took measurements with four hours of light and four hours of dark as an estimate of the daily rate. I think it is more valid to run these tests during the day. Some people run the test for 24 hours and subtract the night time respiration from the daytime respiration, but between day and night there can be a temperature difference of 10°C, which represents a doubling factor.

Q. Did you have any vandalism problems?

A. A lot of people were curious, but I wasn't away long enough (to experience a problem). I only had to drive about 1.5 miles between the two sites. I took readings every half hour.

Q. Did you have any contaminant problems with the membrane?

A. Because of the low dissolved oxygen in the ditch system, I had to go to the high sensitivity membrane on the YSI. You could have problems with that in a highly contaminated system.

Q. Do you have any idea of the dissolved oxygen concentration in the river at night?

A. (G. Gough) Yes, we had a probe in the river overnight. The levels didn't go down as much as we thought they would. It seems to be more related to the tidal action.

A. (W. Duncan) A point that I usually make is that this is a tidal system. There are tidal gates on the Serpentine River, and the water can get fairly stagnant.

2.14 THE ROLE OF THE SALT WEDGE IN RETENTION OF CONTAMINANTS IN THE FRASER RIVER ESTUARY

M. Waldichuk, Biological Sciences, Department of Fisheries and Oceans, West Vancouver Laboratory

The waters in the Fraser River estuary are vertically stratified and seawater penetrates the estuary beneath the freshwater layer in what is commonly referred to as the salt wedge. This seawater moves back and forth with the tide, but may at times have a comparatively long residence time

(>24 hours) in the estuary, depending on various physical conditions that prevail there, especially the tidal range and the Fraser River discharge. Particulate organic material that settles into the salt wedge can contribute to oxygen depletion in the seawater, and this can have serious consequences for fish in the bottom layer or to their food organisms. Sewage and industrial effluent can contribute to the organic particulate load in the salt wedge. During a large tidal range, the salt wedge can penetrate beyond Annacis Island and into various side channels and sloughs, where seawater may be trapped in depressions for extended periods of several weeks or more. Dissolved oxygen depletion can occur in the bottom seawater layer, especially during the warmer months of summer. It can be used as an index of the residence time of the seawater and of the amount of biodegradable organic material present. An example will be shown from dissolved oxygen data for the partially-enclosed former Steveston Cannery Basin, which to some extent simulated a slough, taken over a 25-hr tidal cycle.

Existing data and models, developed on seawater intrusion into the Fraser River, may allow an evaluation of the residence time or rate of replacement of seawater in the salt wedge. From this it might be possible to establish an oxygen budget for the salt wedge, and from that determine the maximum permissible organic loading, in terms of biochemical oxygen demand, in the salt wedge, in order to protect fish and other aquatic organisms present in the salt-wedge habitat.

Questions and Answers:

Q. What was the cause of the rapid depletion of oxygen?

A. Although it was already cooling off, the temperature was higher at that particular time than it would be in a number of months. It is important that the oxygen depletion was not taking place rapidly. The seawater had been sitting for quite a while. The water that was in the head of the basin got carried out on a falling tide and showed up as this pocket of low dissolved oxygen. I should point out that when they discovered that the seawater in this system was causing destruction, they removed the rock wall,

so we don't have quite the same system now. This is a model of what you might expect in some of the sloughs when a slug of seawater comes in on a high tide at low river flow and sits there until the next high tide when the heavier, denser seawater comes in to replace it.

Q. Wasn't a big cannery operating here?

A. That's another point. At the time, there was no Annacis Island sewage treatment plant. There weren't all the pulp mills on the Fraser, but the cannery seemed to discharge much of its offal and organics into the cannery basin. This was taking oxygen out of the system *in situ* and was not an artifact of something entering the system.

2.15 IDENTIFICATION OF ORGANIC CONTAMINANTS IN FISH FROM THE FRASER RIVER ESTUARY

J. Carey, and P.A. Coletta, National Water Research Institute, Environment Canada

The identities of major synthetic organic contaminants in extracts from eight fish from the Fraser River estuary were determined by dual-column capillary gas chromatography using electron capture detectors and a series of external standards. Confirmed identities were obtained for 31 of 45 major peaks in the chromatograms. These compounds included p,p'-DDE, alpha-BHC, hexachlorobenzene, alpha-chlordane, mirex, 2,3,4,6-tetrachloro- and pentachloroanisole and 24 individual PCB congeners. By using observed retention times for the PCB congeners present in the standards and literature values for relative retention times, an additional 8 compounds were tentatively identified and their concentrations estimated from literature values of their response factors relative to those in the standards. It was estimated that a total of 18 individual PCB isomers made up approximately 80% of the PCB's present. Based on these results, it was suggested that the proposed monitoring program for the estuary consider, in addition to those organochlorines mentioned above, the following individual PCB isomers:

2,2',5,5'-tetrachlorobiphenyl (PCB 52)
2,3',4,4'-tetrachlorobiphenyl (PCB 66)
2,4,4',5-tetrachlorobiphenyl (PCB 74)
2,2',3,5'6-pentachlorobiphenyl (PCB 95)
2,2',4,5,5'-pentachlorobiphenyl (PCB 101)

2,3,3',4,4'-pentachlorobiphenyl (PCB 105)
2,3,3',4',6-pentachlorobiphenyl (PCB 110)
2,3',4,4',5-pentachlorobiphenyl (PCB 118)
2,2',3,3',4,4'-hexachlorobiphenyl (PCB 128)
2,2',3,4,4',5'-hexachlorobiphenyl (PCB 138)
2,2',4,4',5,5'-hexachlorobiphenyl (PCB 153)
2,2',3,3',4,4',5-heptachlorobiphenyl (PCB 170)
2,2',3,4,4',5,5'-heptachlorobiphenyl (PCB 180)
2,2',3,4',5,5',6-heptachlorobiphenyl (PCB 187)
2,2',3,3',4,4',5,5'-octachlorobiphenyl (PCB 194)

In addition, five PCB congeners that occurred at significant percentages in Aroclor mixtures had predicted retention times close to those observed for three major peaks. These congeners were: 2,4,4'- and 2,4',5-trichlorobiphenyl (PCB's 28 and 31) which are an unresolvable pair under the analytical conditions used in this study; 2,2',3,4- and 2,3',4',6-tetrachlorobiphenyl (PCB's 41 and 71) which also form an unresolvable pair; and 2,2', 3,3', 4,6-hexachlorobiphenyl (PCB 131). Many of these isomers are included in monitoring programs in other areas, for example all eight of the PCB isomers currently measured in Europe are included as are 12 of the 14 isomers that Health and Welfare Canada has found make up 70% of all human milk PCB's.

Questions and Answers:

Q. Are you saying that we should report all the individual PCB's and not just summarize them by the number of chlorines?

A. I believe we should report them. Some PCB's with very different toxicities are difficult to separate chromatographically. Until we get down to the level of the individual isomers and understand their toxicities, I don't see how we can make any sense of setting objectives.

Q. Do changes in any of these isomers take place inside organisms?

A. I was surprised at the degree of correlation between the composition of the actual Aroclor mixtures and the distribution of PCB's we found in the Fraser. It doesn't always happen that way. Sometimes as the total PCB loss increases, specific isomers begin to disappear. The PCB's will look less and less like Aroclors, and objectives based on Aroclors will be increasingly difficult to justify.

Q. How close are you to publishing some of this work?

A. Some of these results came off the GC on Thursday. We're still sorting it out. We have to buy the standards to confirm some of the lower PCB isomers. We won't be publishing at least until summer.

2.16 THE BIOCONCENTRATION OF CHLOROPHENOLS BY LEECHES AND THEIR USE AS IN SITU BIOLOGICAL MONITORS

K.J. Hall, Westwater Research Centre, U.B.C. and C. Jacob, Fraser River Harbour Commission

Leeches have been used as *in situ* monitors of the biological availability of chlorophenols to estimate the degree of contamination in the North Arm of the Fraser River Estuary, British Columbia, where several forest industry operations use chlorophenols as wood preservatives.

A large spatial and temporal variation was observed in the concentration of 2,3,4,6-tetrachlorophenol (<0.002-15.20 µg/L) and pentachlorophenol (<0.002-2.80 µg/L) in a series of grab and automated water samples. This demonstrated the sporadic nature of discharge of these materials to the river and the necessity to develop a method that could better integrate concentration over time. Leeches readily concentrated the chlorophenols and had a very low depuration rate. When leeches were exposed in the river for a seven day period they bioconcentrated chlorophenols to µg/g levels (28-2946 µg TTCP/g wet wt and 29-846 µg PCP/g wet wt). Based on laboratory bioconcentration studies, leeches provided an estimate of average concentrations from <0.1 to 10 µg/L in the water over the bioassay periods.

Laboratory experiments demonstrated a higher bioconcentration potential at higher temperatures and it took longer to reach steady state tissue concentrations at higher temperatures. At lower pH there was higher bioconcentration of chlorophenols indicating that the un-ionized molecule was adsorbed more readily. There was a good relationship between leech bioconcentration of the un-ionized fraction of the chlorophenol and the partition coefficient ($K_{o/w}$) of the compound.

Questions and Answers:

Q. What is the mechanism of uptake by the leeches?

A. I think it's just respiratory activity. I don't know too much about the physiology of leeches, but it looks like a good absorptive surface. The nice thing about leeches is that they don't get rid of PCP's very easily. We measured parts per million in leeches in a one-week experiment, while levels in fish, which are living out there, are in the parts per billion.

Q. Did you look for pentachloroanisol?

A. No, we were concentrating on the chlorinated phenols, but I suspect it's there. Hal Rogers found some chlorinated anisols in his work off Iona Island.

Q. Do you save some of the concentrate for re-analysis?

A. No, I wouldn't believe the results after that length of time. We stored fish tissue in a freezer in which there were some chloroform extracts of fatty acids. The fish were in double bags, and the chloroform extracts were in tight containers. When we analyzed the fish tissue, it was very high in chloroform.

2.17 CONTAMINATION OF STORMWATER DISCHARGES WITH CHLOROPHENOLS AT SELECTED FRASER RIVER SAWMILLS

D.M. Wilson, Environmental Protection, Environment Canada

Approximately 32 percent of the world's softwood lumber is exported annually from British Columbia. Much of this lumber, especially overseas shipments, must be protected against sapstain and mould attack. Freshly cut lumber is typically treated with a surface application of a 1-2 percent chlorophenate solution. The chlorophenates are formulated as water-soluble sodium salts and are applied to the lumber by either dip or spray application at sawmill and lumber export operations.

Chlorophenate solutions may enter the environment from the sites of chemical storage and application, lumber drip areas and final treated lumber storage yards. Environment Canada and the B. C. Ministry of Environment and

Parks are currently implementing a code of practice to contain chlorophenate releases at sawmill and lumber export operations. Many remedial measures have occurred during mill modernization. However, the forest products industry has not prevented or contained chlorophenate releases from final treated lumber storage sites. Most treated lumber is stored uncovered in storage yards. Chlorophenate residues are either leached or washed off lumber during rainstorm events and contaminated water enters storm drains discharging to the Fraser River and other bodies of water.

A monitoring program was initiated in August 1986 to better define and quantify stormwater discharges from lumber storage yards at five sawmills on the lower Fraser River and at two lumber export terminals in North Vancouver. Catchment basins in lumber storage yards were isolated and sampled at the manhole prior to stormwater discharge to sewer. Manual grab samples of chlorophenate-contaminated stormwater were collected in one litre amber glass bottles and combined as composite samples. Approximately three storm events were monitored at each mill site. Industrial activity, weather conditions, water quality parameters and flow were also determined on each sampling occasion.

A discrete water sample was taken at the beginning of each storm flow into the catchbasins. Seven and one-half minute grab samples were combined into 15 minute composites for approximately the first three hours of storm flow. Thereafter, sampling frequency was decreased to 15 minute grab samples combined into 30 minute composites as flow conditions stabilized. However, if conditions changed on each site (e.g., large increase in flow), the sampling frequency was again increased to the 7.5 minute grab/15 minute composite regime. Storm flows were monitored for an average of 10-12 hours to a maximum of 17 hours from beginning to end.

Preliminary data on chlorophenol concentrations in stormwater indicate that most discharges from treated lumber storage yards are acutely toxic to salmonid fish species.

Questions and Answers

Q. You mentioned that they're doing the chlorophenol treatment of lumber mostly because of the high moisture content. Is kiln drying, which increases the cost of the lumber, an alternative?

A. It is in the interior (of the province), but on the (west) coast. The moisture content is too high.

Q. Since chlorophenol is used for surface protection, why is so much of the shavings contaminated with it? Don't they preserve it after it has been planed?

A. They treat the rough lumber, store it for some time, and then plane it. Afterwards, it is treated again. They don't want the sapstain to develop even on the rough lumber because it will penetrate (into the lumber).

Q. What kind of input or cooperation did you get from industry - financially or otherwise?

A. We got good input from industry. They didn't give us anything financially, but they would contact us every time there was a storm so our people could go out and sample. They provided logistical support.

Q. Did you do this study to establish that there was a problem?

A. Yes. This has been a contentious issue with the forest products industry over either covered storage or wrapped lumber, for example. We got strong resistance from them about any control in the final storage areas. What we were doing was proving to industry that there is a release (of chlorophenols) problem.

Q. I understand that the industry is on the verge of moving away from chlorophenol to other alternatives. I hope that the concern won't go away, because all the alternatives are toxic as well.

A. That's right. We have a committee formed with the Council of Forest Industry to review all the antisapstain alternatives. We're considering all of the environmental aspects, in particular the leaching problem. MacMillan Bloedel Research has done some work on one of the alternatives, TCMTB, to determine whether there is a leaching problem as there is with chlorophenol.

2.18 ORGANIC ANALYTICAL CHEMISTRY AND THE FRASER ESTUARY: IDENTIFICATION OF CONTAMINANTS IN MUNICIPAL WASTEWATER AND FISH

I.H. Rogers, Biological Sciences, Department of Fisheries and Oceans, West Vancouver Laboratory

Studies have been conducted on the mass spectral identification of organic contaminants in municipal and pulp mill wastewaters discharged to the Fraser River system. Levels of chlorophenols, chloroguaiacols and chlorinated hydrocarbons have been measured in water and tissue samples using electron capture gas chromatography with either internal or external standards.

2,3,4,6-tetra (TTCP) and pentachlorophenol (PCP) were measured in Iona Island sewage and rapidly accumulated in exposed juvenile chinook salmon. The fish also accumulated PCB's, DDT and six unknown compounds. There was no evidence of chlorinated organics being formed in the disinfection process. Starry flounders captured south of the Iona jetty also contained these pollutants. However, those captured north of the jetty did not contain the six unknowns - seemingly useful markers of sewage exposure.

Water samples from four stations in the Fraser Estuary in April 1986 contained part per trillion (ppt) levels of PCP and TTCP. They also contained 3,4,5 tri- and tetra-chloroguaiacol, believed mainly of pulp mill origin. The uptake of these compounds in livers of eulachons, captured in April 1986 will be discussed.

Other potentially deleterious organics in Annacis Island sewage include PAH's, non-chlorinated phenols and wood extractives, which will become the focus of future work.

Questions and Answers:

Q. What is the significance of this bioaccumulation? Have you done any studies to determine what happens as a result of this?

A. I don't know the significance. We haven't finished our analyses. We're analyzing gonads and whole fish. Problems with contaminated instruments have held us up for a couple of months.

Q. Have you seen any Mirex in fish?

A. We have run all the standard chlorinated hydrocarbon pesticides. I don't remember if we did Mirex. Just because we haven't seen it doesn't mean it isn't there.

Q. Have you compared the dissolved and particulate-associated contaminants in each effluent?

A. We did at Iona Sewage Treatment Plant (STP). Using a continuous flow centrifuge, we took out the particulates and looked at what was in them. We saw many of the same compounds in the dissolved phase as in the particulates. They were the ones with the high partition coefficients.

Q. What were the three compounds you said were used as the markers for exposure?

A. We don't know what they are. They occur in sewage. They're not chlorinated compounds. The mass spec gives apparent ion peak and an M-15 peak, and that's all the information it gives us.

2.19 GENERAL CONSIDERATIONS REGARDING POLLUTION RESEARCH; DEAS SLOUGH: MUNICIPAL WASTE, FISH BEHAVIOUR AND FUTURE PROJECTS

I.K. Birtwell[1], G.M. Kruzynski[1], I.H. Rogers[1], and M.D. Nassichuk[2]

[1] West Vancouver Laboratory, Biological Sciences, Department of Fisheries and Oceans

[2] Habitat Management Division, Fisheries Branch, Department of Fisheries and Oceans

In endeavouring to protect aquatic organisms from habitat degradation (e.g. contaminants) we must exercise caution and generate statistically sound quantitative information. Modification of aquatic habitats is typically an adverse situation for aquatic organisms and if compromises occur they are usually over human values and needs. The presence of an organism in a particular location does not necessarily mean that it, or the habitat, is healthy. Fish do not always avoid and, in fact may be attracted to, lethal conditions in their environment, nor do they recognize mixing

(dilution) zone concepts wherein water quality standards may be relaxed. Therefore the development of Criteria to protect the aquatic environment must take into account these, and other ecological considerations, and also the cumulative effect of discharges into receiving waters. Also, Criteria for water quality must be based upon the protection of sensitive species, and in the Fraser River estuary wherein marine, estuarine and freshwater organisms occur there should be consistent application of Criteria (for example 9.0 mg/L dissolved oxygen for both inner and outer estuarine areas).

Ecological studies in Deas Slough revealed the presence of twenty-eight species of fish, an extended utilization period by some species, and an abundance of juveniles, some of which had relatively high "apparent growth" rates compared with those in river channel areas. Deas Slough is an important slackwater area for many rearing fish. Temperatures tend to be higher in the upper slough (approx. 4°C) than in the main river, but severe dissolved oxygen depletion occurs in deep dredged pockets opposite two marinas. Full use of the water column by fish is not possible at such times, which typically occur during the main downstream juvenile salmon migration. This work emphasizes the importance of sloughs to fishery resources and the need to maintain or improve water quality, and monitor their condition over time.

Research on the effects of municipal waste on juvenile chinook salmon from the Harrison River stock revealed that higher effluent concentrations jeopardized their survival. Exposure reduced salt water adaptation, induced detoxification - enzyme activity and resulted in a complex response to fish pathogens. Growth was enhanced, and the sexual maturation of male chinook in 5% effluent; androgenic compounds are suspected factors. Organic compounds accumulated in the fish. The combined effect of naturally-occurring parasitic infection, effluent concentration and slightly reduced dissolved oxygen (6.5 mg/L) reduced survival.

The behaviour of juvenile chinook in a water column simulator which provides a vertically stratified, horizontally-flowing water body in which flow, temperature, salinity and dissolved oxygen may be varied and controlled, was examined. Different activity patterns occurred between day and night. There was rapid schooling of the fish in response to the addition of salt water to fresh water. During the spring the chinook moved to deeper and more saline water, but still used the entire vertically stratified water column (fresh water over salt water). The fish (50%) "avoided" imposed low dissolved oxygen levels (between 6.3 and 9.0 mg/L in fresh water) and frequently moved to occupy positions at the halocline. Fish continued to swim into fresh water containing lethal quantities of dissolved oxygen, from a fully air-saturated and deeper salt water zone.

Future work will concentrate on the behaviour of fish after exposure to wood preservatives and continuation of research into the effects of municipal waste in the Fraser River estuary.

Questions and Answers:

Q. You mentioned that the deep holes in the Deas Slough go anoxic. Is that actually affecting the quantity of habitat available? Salmon don't use the deeper part, do they?

A. Salmon tend to be biased toward the surface, but salmon aren't the only fish in that area. The idea that a small piece of degraded habitat has no effect on the larger system can be quite erroneous. That was demonstrated at Iona Island. Relative to the whole Sturgeon Bank - Roberts Bank area there is a relatively small degraded area, but because the fish come into the area to feed on the flooding tide, they are exposed to low oxygen and contaminants. They become stressed, may be killed outright or preyed upon. It indicates that a small area can be significant in some locations, though not necessarily at Deas Slough.

Q. What would you propose to rectify the problem of low dissolved oxygen - opening up the slough to allow flooding?

A. I can't prove it, but I think that the temperature's maintaining a lake-like environment is conducive to the accumulation of fish and the productivity. It may not be desirable to increase the flushing in those areas. Dredging deep pockets is not desirable, but making the sloughs into river channels again is not going to be beneficial. There are seemingly resident sockeye living in the lower Fraser which reach the same size as yearling sockeye living in a lake by October.

Q. Would aerators help?

A. I don't think aerators would be a solution in Deas Slough. The low oxygen is transitory - about two to three weeks - and very deep. The lower values we measured in the surface waters of Deas Slough were about 69% of air saturation. Overall, the condition wasn't bad.

2.20 GENOTOXICITY OF STURGEON BANK SEDIMENT EXTRACTS

D. Walton, Waste Management, Ministry of Environment and Parks, Lower Mainland Region

In the mid-1970's it was observed that elevated frequencies of epidermal papillomas in lemon sole coincided with sources of pollution. In particular 50-60% of the lemon sole collected from Sturgeon Bank near the Iona Island sewage treatment plant discharge had the tumors. It was also observed that there were elevated concentrations of the known carcinogen 3,4-benzopyrene in sediments in close proximity to this discharge.

Recent research has developed genotoxicity tests using fish cells and metabolizing enzymes. These tests were then applied in vitro and in vivo to determine if polycyclic aromatic hydrocarbons and Sturgeon Bank sediment extracts have DNA-damaging activity, and if such DNA damage could be detected in vivo.

These results thereby permit further comment on a chemical etiology for these tumors.

Questions and Answers:

Q. What chemical extraction method did you use?

A. Bruce Dunn, the PAH expert at the Cancer Research Centre, advised using the methylene chloride technique, which is a general, take-whatever-is-there method. The samples were then dried and taken up in DMSO, which was used in the exposures.

Q. What cell lines did you use?

A. There is no fish cell line which is ideal for chromosome aberrations.

R. The RTG II is an excellent one.

A. No, with a 2n of 56 chromosomes it provides very difficult preparations for analysis. I know Dr. Mallins' group have used it, but it's very difficult to analyze. The cell line used in our lab has a 2n of 22, the Chinese hamster ovary cells. I used that in parallel with the fish cells. I developed my own line from the central mudminnow, Umbra limi, which also has 2n of 22 very large chromosomes. DNA repair assays are practical with the RTG. I also used the Umbra limi cell line for DNA repair work.

Q. The skin aberrations bother me. I've done a lot of fishing for groundfish in southeast Alaska, and I've never seen anything like the pictures of the fish from the Fraser River. Even if it is a parasite, I find it hard to believe that it's not due to the stresses from contamination. Would anyone like to comment on that?

A. (P. Chapman) Michael Mix (1986, Mar. Env. Res., vol. 20, issues 1 & 2) did an excellent review, in which he points out that a very high incidence of these lesions can occur even in places like Alaska, which are well away from any contaminant source.

2.21 NUMERICAL SIMULATION OF THE FRASER RIVER PLUME MOVEMENT IN THE STRAIT OF GEORGIA

J.A. Stronach, Pacific Ocean Sciences Ltd., P.B. Crean, Institute of Ocean Science, Department of Fisheries and Oceans, T.S. Murty, Institute of Ocean Science, Department of Fisheries and Oceans

The Fraser River is manifestly the single largest source of fresh water (and associated pollutants) in the Strait of Georgia. Not only controlling the distribution of scalars such as freshwater and sediment, the Fraser

River plume dominates the surface circulation over most of the Strait. A numerical model has been under development since 1975 to describe the dynamical response of surface currents to the combined action of wind, tide and river forcings. This model is based upon the vertical integration of the relevant equations governing mass and momentum conservation within the upper layer, solved by means of an explicit finite difference method, driven by observed winds and river flows, and by tidal forcing derived from a separate barotropic tidal model. Supporting data from various field observations are first reviewed, consisting of vertical salinity sections throughout the Strait of Georgia, high resolution current and salinity profiles in the upper 20 m of the water column, and the tracks of surface drifters obtained during twenty-five periods of intensive field work in 1981 and 1982. Results from the model are then presented. The model is shown first of all to be numerically stable, operating for periods of over thirty days at a time. As well, the seasonal changes in the salinity distribution from Sand Heads to Cape Mudge match observations. Most importantly, the complex flow patterns observed in 1981 and 1982 are in general reproduced by the model. Finally, the results of two short simulations in June and November of 1986 are presented, primarily to indicate the response of the upper layer to strong wind events which occurred during these periods.

No questions

2.22 THE INTERACTION BETWEEN SALINITY INTRUSION AND RIVER FLOW IN THE FRASER ESTUARY

A. Ages, Institute of Ocean Science, Department of Fisheries and Oceans

Without a reasonable knowledge of circulation and advective transport in an estuary, an evaluation of its water quality would be almost meaningless.

In the seaward reaches of the Fraser estuary, members of the Institute of Ocean Sciences at Patricia Bay have been collecting oceanographic data during the past ten years, initially to verify an earlier developed one-dimensional computer model, and more recently to provide a two-dimensional model with current and salinity data.

The one-dimensional model has now been modified to estimate the movement and residence time of contaminants released anywhere in the river's tidal reaches, i.e. between the Strait of Georgia and Chilliwack. The model results have been tested by tracking drifters at some representative discharges and tidal ranges. Although this Lagrangian version of the computer model accurately simulates the water movement in the reaches upstream from the limit of salinity intrusion, there is a noticeable discrepancy between computed and observed trajectories of surface floats in the seaward reaches.

Time series of current and salinity profiles at a variety of stations indicate a significant influence of the salt wedge upon the river flow in the upper layers, suggesting the need for a more sophisticated multi-layer model. This model is being developed at IOS and a great deal of data pertinent to the salinity intrusion and its associated currents have been collected.

A recurring problem in collecting data for this type of model is the time lag between observations at various stations occupied by a moving vessel. Since deployment of chains of instruments from buoys in the channel would be too expensive and too hazardous, an instrument was designed which could be deployed from a helicopter or hovercraft. The probe, manufactured by a local firm, Applied Microsystems, combines an electromagnetic (Marsh McBirney) currentmeter and a salinometer, and measures and stores salinities, temperatures and currents at five-second intervals. After several trials and alterations in the computer unit, the instrument has recently been put to use. It is expected that this new technique, combined with the 2 D model, will provide us with a much more accurate picture of the water movement in the Fraser estuary.

No questions

2.23 ASBESTOS AND TRACE METALS IN SUMAS RIVER SEDIMENTS

H. Schreier, Dept. of Soil Science and Westwater Research Centre, U.B.C.

A landslide in the headwaters of the Sumas River is introducing asbestos rich serpentinitic materials into the stream system. Associated with the chrysotile asbestos are high levels of Ni, Cr, Co, and Mn. The effect of this point source can be traced all the way to the Fraser River confluence and although there are general decreases in trace metals content with increasing distance from the landslide, the trace metal concentrations in the sediments are significantly higher than levels found in regional sediment samples unaffected by the asbestos input. Chrysotile asbestos is unstable at pH < 8.0, and since the pH becomes acidic in the lower section of the Sumas Basin, we expect a release of trace metals. Preliminary evidence suggests that some fish species take up some of the trace metals and additional research is needed to document other potentially toxic effects which might be observed. There is a very close positive relationship between chrysotile asbestos fibre concentrations and discharge rate, and by association between trace metal concentrations and discharge. During peak flow periods the sediment concentrations are very high and drinking water standards for Ni, Mn, and Cr were exceeded on several occasions. There is considerable concern regarding the effects of this material on the aquatic biota and in the use of this material for agricultural purposes.

Questions and Answers:

Q. Is any work going to be done on the impact of asbestos on the eggs and spawning of fish in the Sumas River?

A. None at all. Last summer we did the first work on aquatic biota. We simply collected fish on two occasions to see whether there was anything unusual. We collected many fish, but they were all very small. We need to do a much more thorough study.

Q. Do you have any measurements of asbestos concentrations in Vancouver drinking water? My understanding is that many of the pipes put in years ago were concrete strengthened with asbestos fibers. As our pH is dropping now, they are gradually starting to come into solution. At some point, we should start getting very concerned about asbestos levels in drinking water.

A. The levels of asbestos fibers in Vancouver drinking water are around 10^7, which is a little higher than in the rest of Canada and the U.S., except San Francisco and Seattle. There has been a big controversy about asbestos in cement. Some very aggressive waters tend to leach the fibers out, but all the epidemiological work so far has shown negative results in terms of cancer incidence, except in the San Francisco Bay area, where there is a correlation between incidence of cancer and concentration of asbestos fibers in drinking water. For now, the importance of the effect on human health of asbestos ingested from water has been degraded dramatically because no one can show any conclusive evidence. We are focusing on the land-water interaction, because these sediments are exposed. Once you inhale asbestos fibers, you have real problems.

Q. Would there be any advantage to using dynamite to get that large piece of asbestos rock to slump at a time and in a direction of our choice instead of what nature chooses?

A. The whole formation on Sumas Mountain is underlain by serpentinitic rock. The photograph shows only a small portion which is fairly active now. They have been looking at trying to stabilize the landslide. It's an expensive affair, and I don't think there is any guarantee that it will be stabilized. It's a long-term problem. My suggestion is that if we can chemically weather this material, it may become much less harmful.

2.24 TIME SERIES STUDIES OF SURFACE STABILITY AT THE FRASER RIVER DELTA FRONT, B.C.

J. L. Luternauer, Geological Survey of Canada

Over the past twelve years the Geological Survey of Canada has been monitoring the sedimentary and morphological stability of the tidal flats and slope of the Fraser River delta. Information derived from these studies has been applied not only to environmental impact assessments but also has guided coastal development. Examples of studies that have resulted from the investigations are the following:

Comprehensive Compilation of Air Photo Indices for the Fraser Delta Foreshore (Point Grey to Tsawwassen) 1922-1978 (Leroux and Luternauer 1979), Geological Survey of Canada, Open File 625,

Genesis of Morphologic Features on the Western Delta Front of the Fraser River, British Columbia - Status of Knowledge (Luternauer 1980), in The Coastline of Canada, S.B. McCann, editor, Paper 80-10, pp. 381-396,

Stability of the Fraser River Delta Front (Luternauer and Liam Finn 1983), Canadian Geotechnical Journal, Volume 20, Number 4, pp. 603-616,

Development-Induced Tidal Flat Erosion, Fraser River Delta, British Columbia (Duggan and Luternauer 1985), in Current Research, Part A, Paper 85-1A, pp. 317-326,

First Documented Large Failure at the Fraser River Delta Front, British Columbia (McKenna and Luternauer 1987), in Current Research, Part A, Paper 87-1A, pp. 919-924,

Large-scale Sedimentary Processes in a Trained High-Energy, Sand-Rich Estuary: Fraser River Delta, British Columbia (Kostaschuk and Luternauer 1987), in Current Research, Part A, Paper 87-1A, pp. 727-734,

Preliminary Fieldwork for Thermoluminescence Dating Studies at the Fraser River Delta, British Columbia (Berger and Luternauer 1987), in Current Research, Part A, Paper 87-1A, pp. 901-904,

Tractive Flows Adjacent to Site For Submarine Sewage Pipeline, Fraser River Delta Slope, British Columbia, Canada (Luternauer and MacDonald 1987), Coastal Zone 87, The Fifth Symposium on Coastal and Ocean Management, May 26-29, 1987, Seattle, Washington.

Burrow Distribution of Thalassinidean Shrimp on a Fraser Delta Tidal Flat, British Columbia (Swinbanks and Luternauer 1987), Journal of Paleontology, Volume 61, Number 2, pp. 315-332,

No record of questions

2.25 HARPACTICOID ABUNDANCE AND THERMAL REGIME ON TIDAL FLATS

D. D'Amours, Dept. of Oceanography, U.B.C.

Tidal flats show pronounced temperature fluctuations on a broad range of temporal scales; some of the variability in abundance of the associated fauna is presumably linked to patterns in the ambient thermal regime. Data are presented in support of the hypothesis that abundance of epibenthic harpacticoids is linked to high frequency temperature fluctuations on tidal flats. High frequency temperature fluctuations on M_2-dominated temperate tidal flats recur annually, but in a non-periodic fashion; this could explain some of the variability in the timing of the onset of epibenthic harpacticoid bloom. High frequency temperature fluctuations follow specific tide patterns and are predictable. Objective quality criteria could be defined for the physical characteristics determining the thermal regime on tidal flats (e.g. elevaton, slope, porosity, cover).

No record of questions

2.26 GC/MS ANALYSIS OF SEWAGE EFFLUENT AND SLUDGE FROM ANNACIS, LULU AND IONA ISLAND SEWAGE TREATMENT PLANTS

C. Jacob, Fraser River Harbour Commission

This work was done in 1986-87, the first year of the five-year Fraser River Estuary Water Quality Monitoring Program, initiated by the Provincial Government and assisted by Environmental Protection and the Fraser River Harbour Commission.

Six effluent samples were taken from Lulu Island STP, three effluent and one sludge sample were taken from Annacis Island STP, and one sludge

sample was taken from Iona Island STP. The sewage effluent samples were flow proportional, 5-day composites. The sludge samples were discrete at Iona STP, and 5-day composite at Annacis STP.

Seventeen target compounds or groups of compounds were quantified. Three of the nine effluent samples and the two sludge samples were subjected to confirmatory GC/MS and to full scanning peak identification.

The data were used to calculate environmental loadings. Most of the contaminant levels in Lulu effluent were at lower levels than in Annacis effluent. The daily average environmental loadings were between 9 and 28 times lower at Lulu than at Annacis (flow ratio is only 1:7). The biggest decrease was noted for PAH's and may be due to stormwater input at Annacis. Exceptions were dichlorobenzene and DDE which were detected at higher levels at Lulu. Phthalates were present at higher concentrations than PAH's in both effluents.

The highest environmental loading from the two STPs was nonylphenol, which was present in the effluents at one or two orders of magnitude higher than the other target compounds.

Chlorination/dechlorination of sewage did not seem to influence the concentrations of the target compounds.

PCB's, pentachlorophenol, hexachlorobenzene and trimethylphenanthrenes were not found in the effluents.

The sludge composition from Iona and Annacis STPs was very similar qualitatively but very different quantitatively. Generally, all the target compounds were found at higher levels in the Iona sludge than in the Annacis sludge. The largest increase was for methylated naphthalenes and phenanthrenes which were one order of magnitude higher in the Iona sludge than in the Annacis sludge. Dimethylphenanthrenes were most abundant in Iona sludge, whereas diethylhexylphthalate was most abundant in Annacis sludge.

For further information on this work, contact Les Swain, Water Management Branch, Victoria, 387-9518 or Doug Walton, Waste Management, Surrey, 584-8822. Three separate reports, for each STP, will be forwarded to GVRD in early March, 1987. Access to the data can be obtained through Robert Jones, GVRD, 432-6429.

Questions and Answers:

Q. Can you postulate why the loading of PAH's is about ten times higher in the Iona sludges than in the Annacis sludges? Is it stormwater input?

A. Yes, we can speculate that that is the case.

Q. How can you justify cumulative loadings when you have three and six samples? It can be dangerous because the quality of the sewage varies enormously.

A. No, because the samples are five-day composites. They are taken flow-proportionate, one sample every five days. When I talk about six samples, I am talking about thirty days of operation.

Q. Because the Iona plant, in particular, is subject to combined sewer flows, and any compound may be dependent upon stormwater, the composition is very dependent upon the time of year when you take samples.

A. That is correct. We calculated the environmental loading for that five-month period, and we averaged them per day to get a better idea of what is going on. We have also calculated the concentrations of all the ions of concern in the initial dilution zone and compared the chlorophenol levels with the objectives. They were all below the set Objectives - at Lulu Island two hundred times lower, at Annacis twenty times lower than the set Objectives.

Q. I'd like to mention that the sludge (at Iona) is not discharged to the receiving environment as such. It is a lagoon system.

A. It's not discharged to the water, but it is still in the environment.

3.0 WORK GROUP FINDINGS

Participants were divided into three work groups in the afternoon of the second day to consider the following questions:

1. What is the status of water quality in the Fraser River Estuary by area (i.e., Main Stem, North Arm, Main Arm, Sidechannels, Sloughs, Banks and Boundary Bay)?

2. Is the current information on the Fraser sufficient to answer question 1 (i.e., what are the data gaps?)?

3. What are the problem issues, in order of priority, that should be addressed in each area?

4. What mechanism should be used to address the issue(s)?

5. What are the potential means of obtaining funds for Fraser River research?

The work groups were composed as follows:

WORK GROUP I	WORK GROUP II	WORK GROUP III
P. Chapman	I. Birtwell	M. Clark*
G. Gough	B. Kelso	H. Rogers
D. Walton	G. Kruzynski	M. Waldichuk
C. Jacob	N. Khan	G. Kan
R. Duncan	L. Harding	T. Tuominen
R. Jones	F. Mah	D. Goyette
L. Swain*	M. Nassichuk	S. Sheehan
D. Wilson	R. Dina	B. Chang
T. Tevendale	S. Villeneuve	H. McConnell
S. Samis	M. Pomeroy*	
G. Williams		

*Spokesman

The major findings of the work groups are summarized in Section 3 of the main report. The opinions expressed were not necessarily shared by all groups.